EDUARD JAEGER'S TEST-TYPES (SCHRIFT-SCALEN) AND THE HISTORICAL DEVELOPMENT OF VISION TESTS*

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ABSTRACT

Purpose: Eduard Jaeger's original Test-Types were carefully evaluated: (1) to determine whether Jaeger had maintained a consistent standard, (2) to establish the correct Snellen equivalent for Jaeger's Test-Types, (3) to answer the question of why and how the standard was lost, and (4) to compare the visual angle of optotypes to lines of continuous text.

Methods: All original Viennese editions of Jaeger's Test-Types, as well as first generation United Kingdom (UK) and United States (US) versions, were evaluated. Data were collected objectively using a microruler with a 20X loupe and subjectively using a laser distance-measuring device. The data were analyzed using Microsoft Excel. All previous measurements of Jaeger's Test-Types, objective and subjective, collected over the past 133 years were compared to the current data and to each other.

Results: The correct Snellen equivalent of Jaeger's Test-Types was determined. The visual angle created from the measurement of the height of lowercase letters, without ascenders or descenders, provides an accurate method of assigning a visual angle of a line of continuous text. Comparing the typefaces used in printing first generation UK and US versions of Jaeger's Test-Types to the Viennese editions provided an explanation for the absence of a consistent standard for Jaeger's Test-Types today.

Conclusions: All 10 versions of Jaeger's original Test-Types are virtually identical and established a gold standard for reading vision tests. Jaeger's standard was lost when his Test-Types were first printed in the UK and the US using local typefaces. The Jaeger standard has been re-established. Visual angles determined using continuous text are comparable to those obtained by using optotypes.

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INTRODUCTION

AIMS AND OBJECTIVES

The primary objective of this study is to determine the accuracy with which Jaeger and others produced his Test-Types and to assign the correct Snellen M unit equivalents (distance in meters at which the object in question subtends 5 minutes of arc) to Jaeger's 24 type sizes. In addition, it is hoped that this study will explain how, why, where, and when the Jaeger standard was lost. And finally, it is expected that the data collected in this study will either reestablish Jaeger's standard or disprove the existence of a standard for Jaeger's Test-Types.

The specific goals of this study include:

- To provide an historical perspective of Eduard Jaeger and the origins of modern ophthalmology to appreciate Jaeger's contributions, including his Test-Types, to medical diagnostics
- To explore Jaeger's personality to appreciate the precision and attention to detail he brought to every endeavor
- All authorized versions of Eduard Jaeger's Test-Types will be unearthed and reviewed
- All of the unauthorized versions of Jaeger's Test-Types, printed during his lifetime, will be obtained, evaluated, and compared to Jaeger's authorized Test-Types and to each other
- If Jaeger did establish a consistent standard for his Test-Types, the next objective will be to perform the most accurate evaluation possible of Jaeger's Test-Types, quantitatively by measuring the letter height and empirically using individuals as test subjects, to precisely determine Jaeger's standard
- The next aspect of this study will be to determine the degree of correlation between quantitative (linear letter measurements) and empirical data for Jaeger's Test-Types

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- The question of whether or not it is possible to determine a visual angle for continuous text will also be considered

- All of the data from previous evaluations of Jaeger's Test-Types will be reviewed and compared with each other and with current measurements

- The next issue to be addressed is how the standard for Jaeger's Test-Types was lost

- This study will conclude with the reestablishment of the correct Jaeger Standard, if one exists.

Eduard Jaeger (Fig 1) introduced his Test-Types to the world in 1854. They soon became the de facto world standard for the measurement of reading vision. Under Eduard Jaeger's direction, the Staatsdruckerei [Imperial State Printing House in Vienna] (Fig 2), which contained one of the most complete collections of typefaces in Europe, produced 10 standard editions of Jaeger's Test-Types, all of which were identical from 1854 through 1909. Today Jaeger's Test-Types are still the most commonly accepted method for recording near visual acuity in the United States. However, they are being used incorrectly because the standard that Jaeger established 146 years ago no longer exists.

Because our current method of measuring, recording, and comparing near visual acuity has become arbitrary in that the "J" nomenclature has lost its standard,[1] because visual assessment using Jaeger notation is still required by various government agencies in the United States, and because Eduard Jaeger spent a great deal of time developing a standard, I embarked upon what I thought would be a short journey to uncover this piece of misplaced history. Fourteen years later, with the assistance of numerous librarians and medical historians around the world, this goal has finally been accomplished.

As I began to uncover all of the editions of Jaeger's Test-Types, most of which exist only in Vienna, I became curious about Eduard Jaeger the person and developed a biographical sketch of him that reveals an individual who was obsessed with detail. Indeed, he was the ideal person to develop the most accurate, practical, and universally accepted visual acuity test of its era. Jaeger's vision test, *Schrift-Scalen*, which literally translates as type-scales (renamed Test-Types by William Wood & Co when first printed in the United States), continued in popularity throughout the world well into the end of the first decade of the 20th century and remains in use in the US to this day.

JAEGER'S TEST-TYPES

The success of Jaeger's Test-Types was in part due to the fact that it was the first practical test of this type that was universally available. It had a small-book format, making it easy to use (an even more popular pocket edition of the Test-Types was printed only once, in 1865). It contained a great range of type sizes, was multilingual (printed in 12 languages), and possessed high-quality print and paper, being printed by the Viennese Staatsdruckerei, one of the premier printing houses of the period.

Including the first edition of his Test-Types as an appendix in his book *Ueber Staar und Staaroperationen* [On Cataracts and Cataract Operations] (Fig 3) assured a broad initial distribution and in so doing created a ready market for this vision test. Jaeger or his publisher must have realized the importance of marketing this new concept as a product if it were to succeed. Several additional facts support the theory that marketing was a part of the mindset of Jaeger, his publisher, or both:

- Jaeger always printed his Test-Types in at least the 3 primary European languages: German, French, and English. This was quite unique for that historical period

- The second edition of his Test-Types was printed in 10 languages

- The third and most of the subsequent editions were distributed simultaneously in both Vienna and Paris thereby further broadening their audience and distribution.

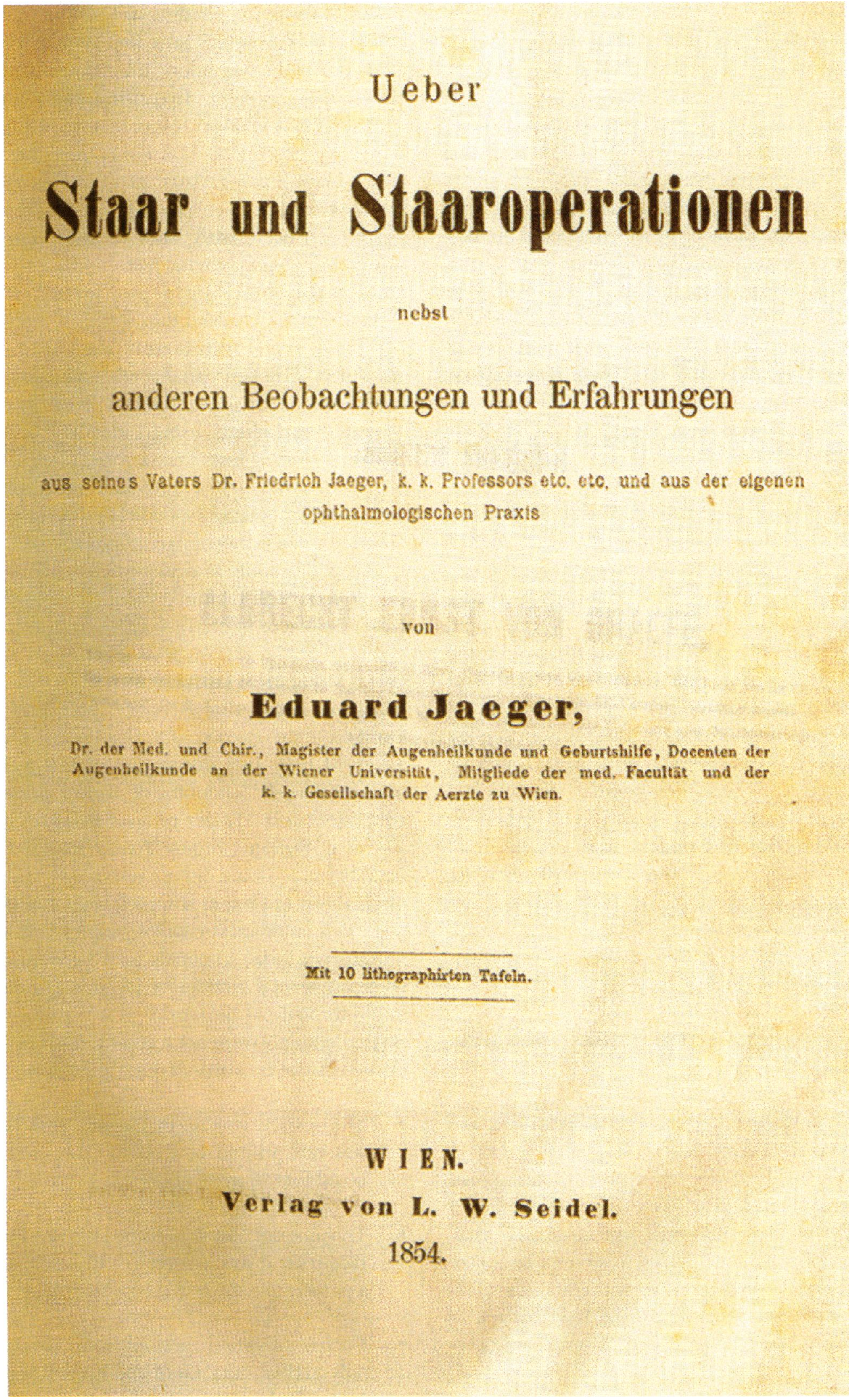
TEST-TYPES VERSUS OPTOTYPES

Perhaps Jaeger's early success helped create the climate of professional jealousy that ultimately developed between Jaeger and Herman Snellen and may be responsible for the complete absence of Jaeger's vision test in Europe today. Two main schools of thought coexisted at that time regarding the measurement and recording of visual acuity: One promoted by Jaeger, the other by Snellen.

These men had diametrically opposed viewpoints in this controversy. Jaeger and his proponents believed that Test-Types consisting of continuous text were the best method of assessing visual function. They reasoned that this type of test best reflected the actual tasks individuals were having to perform in their daily lives. The most common visual complaint of patients was the inability to read words and sentences and not individual letters. For example, a typical, important, and practical task was reading the newspaper. Isolated uppercase letters as proposed by Snellen, optotypes, although more amenable to scientific measurements did not truly reflect the actual visual task individuals were required to perform in the real world.

FIGURE 1
Eduard Jaeger Ritter von Jaxtthal, born in Vienna June 25, 1818, and died in Vienna July 5, 1884. He is best known for his Test-Types (*Schrift-Scalen*) and atlases of the ocular fundus. He was the first person to describe diabetic retinopathy and the optic nerve changes seen in glaucoma.

FIGURE 2
Imperial Royal Court and State Printing Establishment (*kaiserlich-königlichen Hof und Staatsdruckerei*) in Vienna, circa 1854. This printing house produced all of Eduard Jaeger's Test-Types (*Schrift-Scalen*) from 1854 through 1909 and Jaeger's atlases.



Ueber

Staar und Staaroperationen

nebst

anderen Beobachtungen und Erfahrungen

aus seines Vaters Dr. Friedrich Jaeger, k. k. Professors etc. etc. und aus der eigenen ophthalmologischen Praxis

von

Eduard Jaeger,

Dr. der Med. und Chir., Magister der Augenheilkunde und Geburtshilfe, Docenten der Augenheilkunde an der Wiener Universität, Mitgliede der med. Facultät und der k. k. Gesellschaft der Aerzte zu Wien.

Mit 10 lithographirten Tafeln.

WIEN.

Verlag von L. W. Seidel.

1854.

FIGURE 3

Ueber Staar und Staaroperationen [On Cataracts and Cataract Operations, with other observations and experiences from the ophthalmological practices of Eduard Jaeger and his father, Friedrich Jaeger.] This book includes the first printing of Jaeger's Test-Types (*Schrift-Scalen*) as an appendix.

Jaeger's Test-Types were therefore a useful and practical tool for quickly assessing primarily reading vision, although Jaeger and, apparently, Franciscus Cornelis Donders, Snellen's mentor, used the larger letters in Jaeger's Test-Types to measure distance vision as well, despite the fact that the distance at which the type should be read was never specified. Jaeger and many other ophthalmologists of the day preferred to simply record the number of the size of the type and the distance at which it could be easily read as a way of documenting visual acuity.

Jaeger's test was a practical method of measuring the ability of individuals to read text. It was easy to administer, simple for the patient to use because it was composed of familiar type, portable, and contained a great range of type sizes in several languages. As a tool for assessing and comparing reading vision, it was ideal. Jaeger single-handedly created a standard where none had previously existed. The introduction of Jaeger's Test-Types made the measurement and comparison of visual acuity a simple task.

The second camp of ophthalmologists was aligned with Snellen. These individuals felt strongly that the distance at which either samples of continuous text or individual optotypes would subtend 5 minutes of arc should be noted for each size of type. This group preferred using optotypes for testing vision rather than continuous text because they felt that their method was the only reproducible and accurate method for assessing vision. Snellen was promoting his eye charts at about the same time that Jaeger's Test-Types were becoming popular. Snellen had a vested interest in promoting the optotypes he had developed under the direction of Donders, to the exclusion of other vision tests. Jaeger argued that it was difficult, if not impossible, to assign a visual angle to continuous text and also that doing so was unnecessary. Until now, as a result of the research presented in this paper, this argument remained unresolved.

VISION TESTS: CONTINUOUS TEXT VERSUS INDIVIDUAL LETTERS

From the time that Jaeger introduced his Test-Types and Snellen his optotypes, they and their colleagues argued about comparing continuous text with optotypes. Jaeger argued that recognizing continuous text was a completely different function than identifying individual optotypes and that, therefore, it did not make much sense to attempt to equate the two. Reading continuous text does not require the ability to recognize each individual letter (the task that one is asked to perform when reading a line of unrelated optotypes).

It is possible in some circumstances to easily recognize words with missing letters almost as easily as when all letters are present: an analog function. The fact that one's ability to recognize continuous text is not impaired by covering the descenders in a line of text but is markedly impaired if the ascenders are covered adds further support to this argument. In contrast, the ability to recognize individual block letters is much more of a digital function. With few exceptions, you either recognize the letter or not. In producing visual acuity tests using optotypes, every effort has been made to eliminate letters that are easily confused with one another, emphasizing the attempt to create a digital test.

It is also interesting to speculate as to why Jaeger's eye tests ultimately evolved into a test of reading vision only and Snellen's eye tests became the universal standard for measuring distance visual acuity. The simplest and most likely explanation is that Snellen primarily produced wall-mounted eye charts using individual optotypes. Even Snellen's reading tests were either composed of individual letters or contained a limited number of lines of text. Alternatively, Jaeger specifically developed a reading vision test consisting of paragraphs of text using universally acceptable fonts in a small booklet format. He never developed a wall-mounted vision test and simply used the larger typefaces in his Test-Types for this purpose.

USING SNELLEN M (METER) UNITS

On more than one occasion, Snellen tried to get Jaeger to assign M units (the distance in meters at which the test object subtends 5 minutes of arc) to Jaeger's samples of continuous text. Jaeger refused to do so; however, Ernst Fuchs, at Snellen's urging, finally supplied these missing data[2] but in so doing did not just assign M units to Jaeger's original text but rather completely altered Jaeger's reading test. This modified version of Jaeger's Test-Types is almost nonexistent today (3 copies exist in Viennese libraries),[3,4] whereas, several editions of Jaeger's original work can be found throughout the world. It is therefore likely that the revised editions were not a commercial success. This lack of success can be attributed to the following factors:

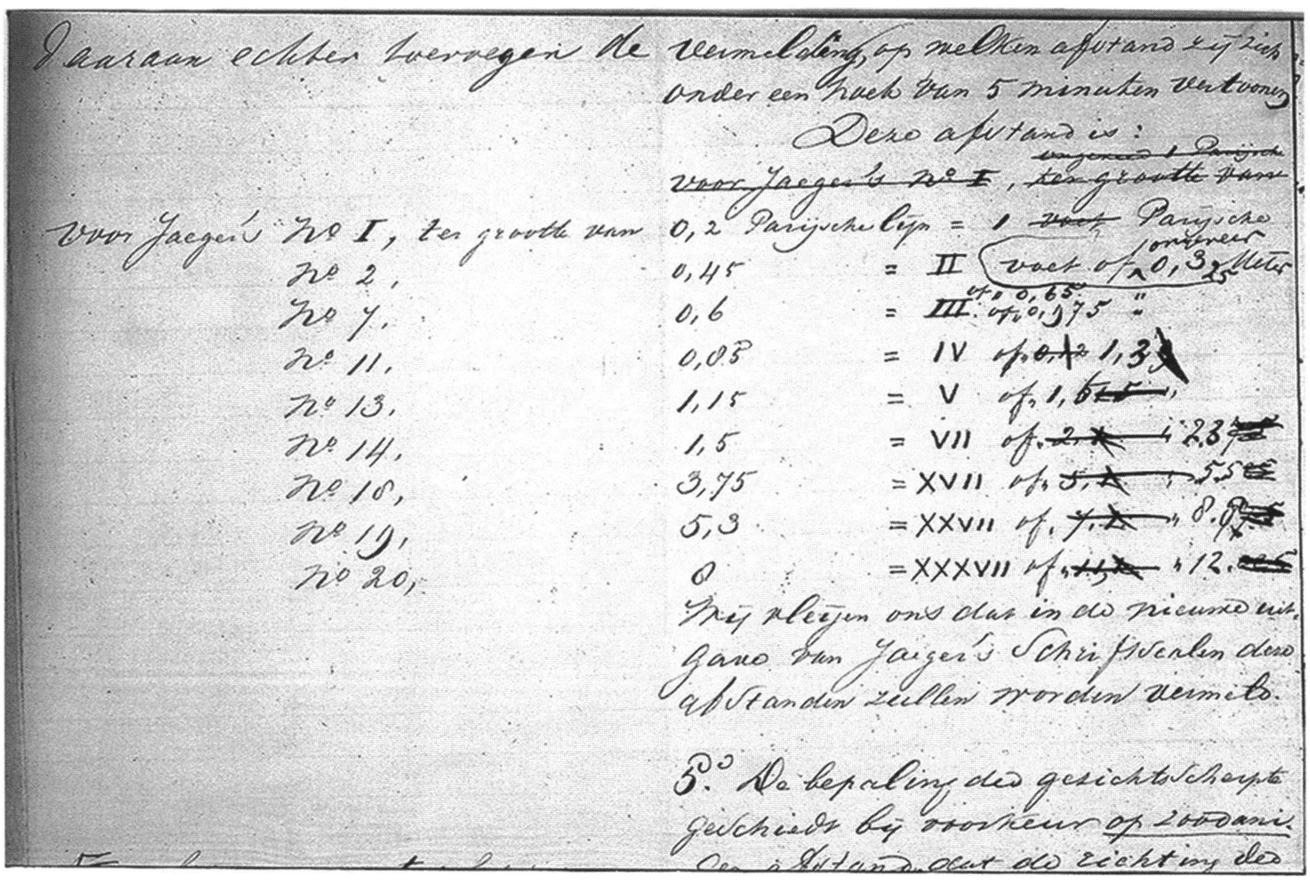
- The revised version of Jaeger's Test-Types by Fuchs was not printed in Fraktur (the most easily recognized font of the day)
- The amount of text presented in the Fuchs version of Jaeger's test was limited to 1 line or less as opposed to a paragraph, as was the case with Jaeger's original test
- Fuchs's modified editions were printed in German only rather than German, French, and English, as Jaeger had always done.

Snellen's handwritten revision of *Optometrologie die*

Functionsprüfungen des Auges, published in 1873 with Landolt, reveals another interesting facet of the struggle between Snellen and Jaeger. Corrections included with Snellen's handwritten manuscript show numerous alterations to the M unit values Snellen was attempting to assign to Jaeger's text. This suggests that even Herman Snellen had great difficulty assigning appropriate M unit values to Jaeger's Test-Types.[5] The values Snellen subsequently published are similar to those found in the current study for the standard English and French text.

Snellen is complimentary of Jaeger's Test-Types, as were most practicing ophthalmologists of the day. For testing reading vision, Snellen states, "We recommend von Jaeger's excellent print scales, where the smaller sizes in particular stand out because of the sharp printing and their regularity of form and clarity. However, it is necessary to show the distance at which they appear under an angle of 5 minutes." He then provides the missing numbers (Fig 4) followed by the comment, "We are glad to have reason to hope that the data for these distances will not be missing in the new edition of von Jaeger's type scales."[5] Jaeger never added the numbers to his Test-Types.

Current measurements of the average lowercase letter height of Jaeger's Test-Types obtained using a Microscale are virtually identical to empirical determinations for all values up to and including J19. In addition, according to Schnabel, one of Jaeger's students who published a complete set of measurements of Jaeger's Test-Types,[6] the larger letters are also comparable if they are spaced properly, thereby avoiding the crowding phenomena. Regardless of Jaeger's thoughts to the contrary and in spite of generally accepted dogma that tests using optotypes cannot be compared with tests that utilize continuous text, the two appear to measure similar functions. So despite Jaeger's not wanting to assign Snellen M units to his Test-Types, it appears that this can be done accurately.


Daaraan echter toevoegen de vermelding, op welken afstand zij zich onder een hoek van 5 minuten vertoonen.
Deze afstand is:
~~voor Jaeger's No I, ter grootte van~~ ongeveer 1 Parijsche

voor Jaeger's No I, ter grootte van	0,2 Parijsche lijn	= 1 ~~voet~~ Parijsche	
No 2,	0,45	= II	voet of 0,3 Meter
No 7,	0,6	= III	of 0,375
No 11,	0,85	= IV	of 1,3
No 13,	1,15	= V	of 1,6
No 14,	1,5	= VII	of 2,25
No 18,	3,75	= XVII	of 5,5
No 19,	5,3	= XXVII	of 8,0
No 20,	8	= XXXVII	of 12.

Wij vleijen ons dat in de nieuwe uitgave van Jaeger's Schriftscalen deze afstanden zullen worden vermeld.

5o De bepaling der gezichtsscherpte geschiedt bij voorkeur op zoodanigen afstand dat de richting der

FIGURE 4

Handwritten manuscript by Herman Snellen, with corrections, demonstrating difficulty he had in assigning correct M units (meter distance at which the text subtends 5' of arc) to Jaeger's continuous text (Test-Types). Assigned values are implied to be empirically determined; however, details of how values were measured are not included in the paper. These data were published as noted, these being the final corrections, by Snellen in *Optometrologie. Die functionsprüfungen des Auges*[5] in 1873. Snellen's data, including the M unit values he determined for Jaeger's Test-Types, are consistent with those of all other investigators with one exception: his assigned values for J19 and J20 are closer to the calculated values (from letter height measurements) than those determined by all other investigators.

Perhaps the reason for Jaeger's refusal to assign M units was more personal or political rather than real or practical. Jaeger developed a practical reading vision test that would mirror common everyday reading tasks (eg, the ability to read the widely circulated books and newspapers of his day). It would therefore make absolute sense to select similar type samples from the broad range of type specimens available at the *Staatsdruckerei* in Vienna, which were in common usage for producing most printed works of the period. This is what Jaeger did.

CONCLUSION

What difference does it make to anyone today if the Jaeger standard is lost? Does the absence of a precise standard have any significant effect on anyone or anything, or is this just an issue of being precise in collecting data? Does it really matter if the actual recorded Jaeger values from examiner-to-examiner, eyechart-to-eyechart, or patient-to-patient are incorrect by as much as 2 or 3 Jaeger numbers? Or is this just a futile exercise to impose precision in an area where precision is unimportant and where this lack of precision will have little or no impact? As we enter a new millennium, with our ability to resize and completely alter or replace fonts at the touch of a few computer keystrokes, we should take a moment to gaze back to the last half of the 19th century and appreciate the importance of Jaeger's work. I believe that the Test-Types of Eduard Jaeger, which were first introduced 146 years ago and which survive today despite numerous attempts to rid the world of them, must–as many of Jaeger's contemporaries stated–be a most useful and practical tool for testing vision. Jaeger's Test-Types were universally accepted during his lifetime and persist through today despite numerous critics both then and now. One cannot deny their resilience.

If I were allowed but one stated goal of my journey, it would be to assign the correct Snellen M unit to each of Jaeger's 24 sizes of type in order to restore their lost standard and thereby ensure that they are used correctly as Jaeger had intended. In so doing, Jaeger's Test-Types, with associated nomenclature, could assume their rightful place in the documentation of near visual acuity as we move into the next century–the place they occupied during the last half of the 19th century.

It must be remembered that until Jaeger developed his Test-Types, there was a total lack of standard for measuring, recording, and comparing visual acuity. It would certainly be a disservice, not only to Eduard Jaeger but also to modern ophthalmology, if this lack of precision to this critical measurement in ophthalmology were allowed to persist. Clarification of this issue with the introduction of the correct corresponding Snellen M units will ultimately facilitate the transition to the universal acceptance of the Snellen M unit. This may ultimately lead to a movement away from the use of Jaeger's units, which then can be allowed to assume their rightful place in history.

REVIEW OF THE LITERATURE

CHRONOLOGY OF VISUAL ACUITY TESTING

The earliest mention of an eye test to measure visual acuity is described by Kurt Müller-Wilhelmshaven. He states that the oldest eye examination was conducted by the Egyptians in approximately 3000 BC in connection with the star Sirius in the constellation Canis Major.[7] In antiquity Sirius, which was called "Sothes," played a major role in calendar calculations (eg, the Sothes year and Sothes period). If an Egyptian wished to go hunting, he first had to submit to a "hunter's test," in which he had to recognize Sirius. Only by successfully completing this task was he admitted to the hunters' fraternity. Since Sirius is a −1.46 magnitude star, which, with the exception of our sun, is the brightest star in our heavens, it would appear to have limited value as a vision test because it is easily seen by individuals with visual acuities of much less than 20/20.

However, ancient astronomers were aware of binary stars, 2 distinct stars appearing close together. They used the ability of an individual to resolve a pair of closely aligned stars as a test of vision. Canis Major contains a binary star that would be useful for this purpose, h3945. One of the stars in this pair is magnitude 5 the other is approximately magnitude 6. These 2 stars are separated by 0.44 minutes of arc.[8]

The best-known doublet star is located in the Big Dipper of the constellation Ursa Major. The second star in the handle of the Big Dipper is composed of the magnitude 4 star Alcor and the second magnitude star Mizar. These 2 stars are separated by 11.8 minutes of arc[8] and are easily resolved by the naked eye.[9] The combination of Sirius, h3945 and Alcor and Mizar would have provided the ancient Egyptians with a test of vision.

The ophthalmologist Dr Rudolph Schirmer reports a proper eye examination in ancient Egypt in the *Klinische Monatsblätter für Augenheilkunde* as follows:

> In the mythological battle of falcon-headed Horus with the wild warrior god Seth (Seth has the head of a no longer identifiable desert animal), Horus' left eye (Horus' eye = the moon) is injured and then healed by the ibis-headed god Thoth, the patron of scribes and scholars. Through this act, Thoth himself also becomes the moon god, who restores the waning moon in the cosmic rhythm and thus makes the heavenly body once more the "intact eye of Horus" (Erman). The sun god Ra conducts a test of the visual ability of the damaged eye by covering the intact 1 with his hand while Horus must look at 2 objects of different size: a black line, and then a black pig (in which Seth is concealed).[7,10,11]

In 1623, Daça de Valdes (Fig 5) published a book entitled *Uso De Los Antoios*[12] [The Use of Eyeglasses] (Fig 6), which described the fitting of spectacles. Chapter 9 of this book (Fig 7A) contains a description of the use of a line of mustard seeds (said to be the smallest of seeds as noted in the Bible)[13-15] for assessing vision (Fig 7B). Daça de Valdes states that in remote places many people were unable to see properly because of the unavailability of appropriate glasses. He therefore developed a simple method for individuals to determine their own refractive errors and thereby be able to order the correct spectacle correction "from where glasses are made plentifully." The actual test was described as follows:

> Nearsighted individuals should first of all remove their glasses and then place a row of one dozen mustard seeds in a line using a needle on a white sheet of paper. The individual should then distance himself from the seeds until they can just be counted (Fig 7B). At this point, the distance from the eyes to the line of mustard seeds should be measured and using a scale (Fig 7C) provided by Daça de Valdes, the proper spectacle correction, could then be ordered.[12(pp28,29),16(pp35,36),17(pp143,144),18(pp143,144)]

FIGURE 5
Benito Daça de Valdez (1591-1634) licentiate and notary of the holy office (Inquisition) at Seville. He published the first book on the use and fitting of eyeglasses, *Uso de los Antoios*, in Seville in 1623.


VSO
DE LOS ANTOIOS
PARA TODO GENERO DE VISTAS:
En que ſe enſeña a conocer los grados que a cada vno le faltan de ſu viſta, y los que tienen qualeſquier antojos.

Y ASSI MISMO A QVE TIEMPO SE AN de vſar, y como ſe pediran en auſencia, con otros auiſos importantes, a la vtilidad y conſeruacion de la viſta.

POR EL L. BENITO DAÇA DE VALDES,
Notario de el Santo Oficio de la Ciudad de Sevilla.

DEDICADO A NVESTRA SEÑORA de la Fuenſanta de la Ciudad de Cordoua.

CON PRIVILEGIO.
Impreſſo en Seuilla, por Diego Perez. Año de 1623.

FIGURE 6
[the Use of Eyeglasses, for all types of vision with additional lessons on various visual defects]. This book contains the first written description of this topic and was written by Benito Daça de Valdez (1591-1634), licentiate and notary of the holy office (Inquisition) at Seville. This book was published in Seville in 1623.

Daça de Valdes also described the use of a book with small print to measure visual acuity by determining the distance at which the text could be seen clearly.[12(p48),16(p44),17(p159),18(p159)] In addition, he mentions using a sample of "fine and delicate" print as a more precise "scale" for testing vision[12(pp52,53),16(p48),17(pp164,165),18(pp164,165)] and the use of prayer and mass books, with their various type sizes, as a means of assessing vision.[12(p94),16(p85),17(p224),18(p224)] Following in the same paragraph there is a discussion extolling merchants of pearls, precious stones, and linen to be very careful in checking their glasses and vision so that they would not be deceived in what they bought or sold.

Fifty years later, Robert Hooke performed the first experiments to measure visual acuity for a grating pattern. Even then many misconceptions about the limits of visual

CAPITVLO IX.

PARA SABER PEDIR ANTOIOS en auſencia, los cortos de viſta natural.

Valquiera falta de viſta, tiene ſus gra dos, de mas y menos cortedad à don de alcança, como el corto de viſta, que

FIGURE 7A
Chapter 9, page 28, of *Uso de los Antoios* by Daça de Valdez, which contains description of testing visual acuity by using a line of mustard seeds on a sheet of white paper. Chapter is entitled [How to order eyeglasses when having difficulty with near vision.]

LIB. II. DE EL VSO

que quanto mas llega à los ojos lo que mira, tanto menos vee. Y porque en partes remotas, ſe quedan muchos ſin ver, por falta de antojos en que aya de todos grados. Pornemos aqui vna manera de regla, para que cada vno ſepa los grados de viſta que le faltan, y los embie à pedir donde ſe labran, ó los aya cumplidamente. Siendo pues corto de viſta, ſe à de quitar los antojos que tuviere pueſtos, y luego à de tomar haſta vna dozena de granos de moſtaza, y echarlos en vn papel blanco, y con vna punta de aguja, ò alfiler, ponerlos en hilera, vno junto á otro, como ſi eſtuvieſſen enſartados. Y apartando la viſta de los granos todo lo que pudiere ſin que los pierda, buelva los â contar vno à vno con la punta de el aguja, como para ver ſi eſtan cabales los que puſo, y entonces ſin levantar ni baxar mas el roſtro, mida con vna cañuela, ò palillo la diſtancia q̃ ay deſde el entrecejo de los ojos, haſta los granos que pudo contar, y midaſe luego eſta cañuela, ò palillo en la medida ſiguiente, y el numero que ſeñalare deſde el punto de la eſtrella, eſſos grados le faltan de viſta, y por eſſos de concavo tiene de embiar para ver à lexos

FIGURE 7B
Chapter 9 of *Uso de los Antoios* by Daça de Valdez, which contains first formal written description of vision testing and fitting of spectacles: "Siendo pues corto de vifta, fe á de quitar los antojos que tuviere pueftos y luego á de tomar hafta vna dozena de granos de moftaza [dozen mustard seeds], y echarlos en vn papel blanco [place them onto a sheet of white paper], y con vna punta de aguja, ò alfiler, ponerlos en hilera, vna junto á otro [using a needle, place them in a row], como fi eftuvieffen en fartados."

perfectamente. Y lo miſmo pueden hazer las mugeres de eſta viſta corta por naturaleza. Y começamos deſde cinco grados, por que a buena diſcrecion, puede cada vno juzgar, q̃ mientras mas apartado contàre los granos, menos grados á meneſter. Y tambien por no dar mas lugar la pequeñez de eſte libro à que ſe apuren los primeros grados, ſiendo tan poca la falta que hazen, pues ſin ellos ſe puede paſſar la viſta, y no ay dificultad en conocerſe.

H CAPI-

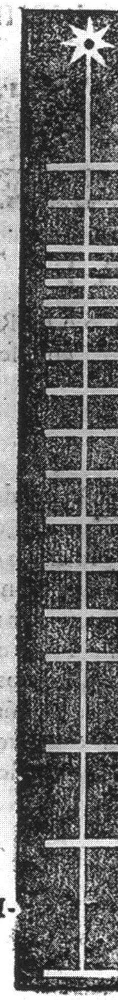


FIGURE 7C
Chapter 9, page 29, of *Uso de los Antoios* by Daça de Valdez, which contains the first written description of testing visual acuity. Above "ruler" is used by an individual to determine distance at which a line of mustard seeds are seen clearly. Number obtained from ruler can then be provided to an "optician," who can in turn prepare an appropriate pair of spectables.

acuity persisted. One rather famous story that was repeated by Cicero, Strabo, Phliny the Elder, and Aelian recounts the ability of an individual with exceptional vision to be able to count the number of vessels in the fleet at Carthage from Marsala in Sicily, approximately 200 kilometers away. This task would be impossible at the distance described because of the curvature of the earth; however, clearly, this method of assessing visual acuity in ancient times existed. This story was still quoted by Robert Boyle[19] in 1690.

The next mention of vision testing in the literature, nearly 50 years later, is described by James Jurin in 1738. Jurin's essay upon distinct and indistinct vision in *A Compleat System of Opticks* in 4 books by Robert Smith describes a test of visual acuity as follows: "Take a title-page of a book, in which there is print of 3 or 4 different sizes and first place the book at such a distance, as that every sort of print may without straining of the eye appear perfectly distinct."[20]

Ayscough, an Optician in London in 1750, noted the following: "Every good Eye has one certain Diftance (or nearly fo) of feeing a common Print to read with Eafe."[21(p9),22(p14)] Ayscough also made the following observation:

> In order to make a proper Choice (of Glaffes), hold a fmall Print at the Diftance, at which you was ufed to read diftinctly, when your Eyes were good, which with moft People is about 9 or 10 Inches, then chufe a Pair of Spectacles of fuch a Degree of Convexity as renders the Letters as plain as they ufed to appear before your Sight was defective.[21(p10),22(p15)]

Ayscough notes one final observation in his book:

> A Perfon whofe refidence is in the Country, and has no Opportunity of making that Trial, may nearly as well be fitted by the following Method; viz. Let the Perfon take a common Print, and move it to the Eye, till he fees diftinctly, then meafure the exact Diftance from the Eye to the Paper: By fending an Account of that Diftance, they may be fitted to a fufficient Degree of Exactnefs.[21,(p11)22(p16)]

Tobias Mayer[23-26] in 1752 and 1754 used a series of 5 figures to measure the limits of vision:

- Dots of varying sizes
- Figures containing equal stripes
- Figures containing unequal stripes
- A square of black lattice containing small white squares
- A small checkerboard (Fig 8).

Mayer determined the visual angle for objects separated by an interval equal to their diameter to be 60 seconds. He made several other pertinent observations regarding visual acuity, including:

- The relationship between light and visual acuity is not linear
- Inexactitudes of up to one half of one foot are possible in subjective experiments.

Mayer was also the first individual to use the notation "S" for visual acuity. His general formula was $S = n\sqrt{^{3}a}$, where S equals the visual angle expressed in seconds, *n* is a unique constant specific for each object being observed, and *a* equals the distance from the light to the object expressed in Paris feet. Subsequently, Donders used the same letter in his formula but as a representation of the German work Sehschärfe, meaning visual acuity.

George Adams (1789), in his *Essay on Vision*, described a vision test used on a 5-year-old boy. "He faw letters which were written on bits of paper, fo as to name them with equal eafe, and at equal diftances, with 1 eye as the other children.[27(p151),28(p155)] The foregoing obfervations were carefully made, by writing fingle letters on fhreds of paper, and laying wagers with the child, that he could not read them when they were prefented at certain diftances, and in certain directions."[27(p151),28(p156)]

In 1801, Boulanger published a book entitled *Directions for Maintaining the Health of the Eyes*. In this book, the provincial reader who requires eyeglasses is advised to take any text and place it at the best distance for visibility, then measure the distance from the text to the eye and the height of the letters. Each eye is to be measured separately. This information can then be provided to an optician at a remote location from the patient, who can then, in turn, make the proper spectacle correction, without having to examine the individual in person.[29]

In 1810, Chevallier described a method for measuring an individual for proper power of glasses when a well-provisioned store was unavailable. A well-known book

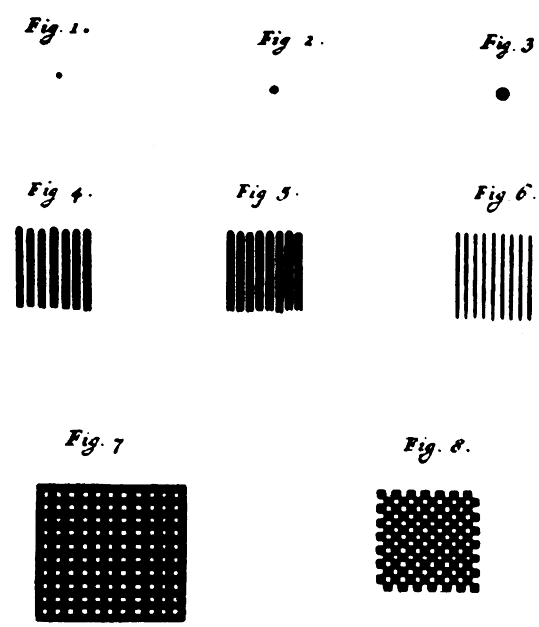


FIGURE 8
Various objects and test patterns used by Tobias Mayer (1723-1762) to assess limits of visual acuity.

such as *l'Encyclopédie, le Voltaire Braumarchais* should be used to determine the distance at which text appears clear. Once this distance has been determined, a string or more appropriate measuring instrument can be used to measure the distance between the eye and the book. This information can then be provided to an optician, some distance from the person requiring the spectacle correction. The optician would then be able to make the proper spectacle correction.[30,31]

In 1813, James Ware described, in an article entitled "Observations Relative To The Near And Distant Sight Of Different Persons," a 45-year-old woman who was near-sighted from infancy in whom the "sight had become so confused in both eyes, that she saw nothing distinctly, and was unable to read letters, of the size that are used in the printed *Transactions of the Royal Society*, either with or without glass."[32(p40)] Several other references to reading type of various sizes are also made throughout the article. "With a glass of this description I can read the smallest print…"[32(p45)] "A woman, about fifty years of age, of full habit, who for several years had been obliged to make use of convex glasses, in order to read small print…"[32(p47)]

In 1816 and 1823, Gottfried Tauber published a booklet entitled *Directions for Patients Wishing to Obtain Glasses* from the Optical-Oculistical Institute in Leipzig.[33,34] Tauber was the owner of the Optical-Oculistical Institute and appears to have been somewhat obsessive about obtaining accurate visual acuities from his patients. He had a page of text in the booklet printed using a special technique, which produced an image of extraordinary quality and would, therefore, be well suited for testing vision. Pergens reproduced a section of this test page in *Annales D'Oculistique*.[25] Interestingly enough, the text for testing vision that Pergens attributes to Tauber is located throughout one paragraph in both the 1816 and 1823 editions of Tauber's booklet and does not appear as a separate vision test.[33,34] However, the complete text is found in Holke's dissertation as an appendix[35] (Figs 9 and 10). Tauber's observations were conducted using one size of type only and served as a basis for Holke's work and subsequent thesis.

Pergens states that Holke's thesis had a second rare appendix that contained an additional test of vision using smaller type. The one copy of his thesis that I have been able to examine has only one appendix and it contains Tauber's large-sized text only.

William Lawrence describes various vision tests in his text entitled *A Treatise on the Diseases of the Eye*[36] first published in the US in 1834. He notes that "far-sighted persons can see distant inscriptions, or distinguish the hour by a distant church clock, when they cannot read a common print held in their own hands, or see the figures and hands of a watch."[36(p464)] Individuals with near-sightedness are described as follows:

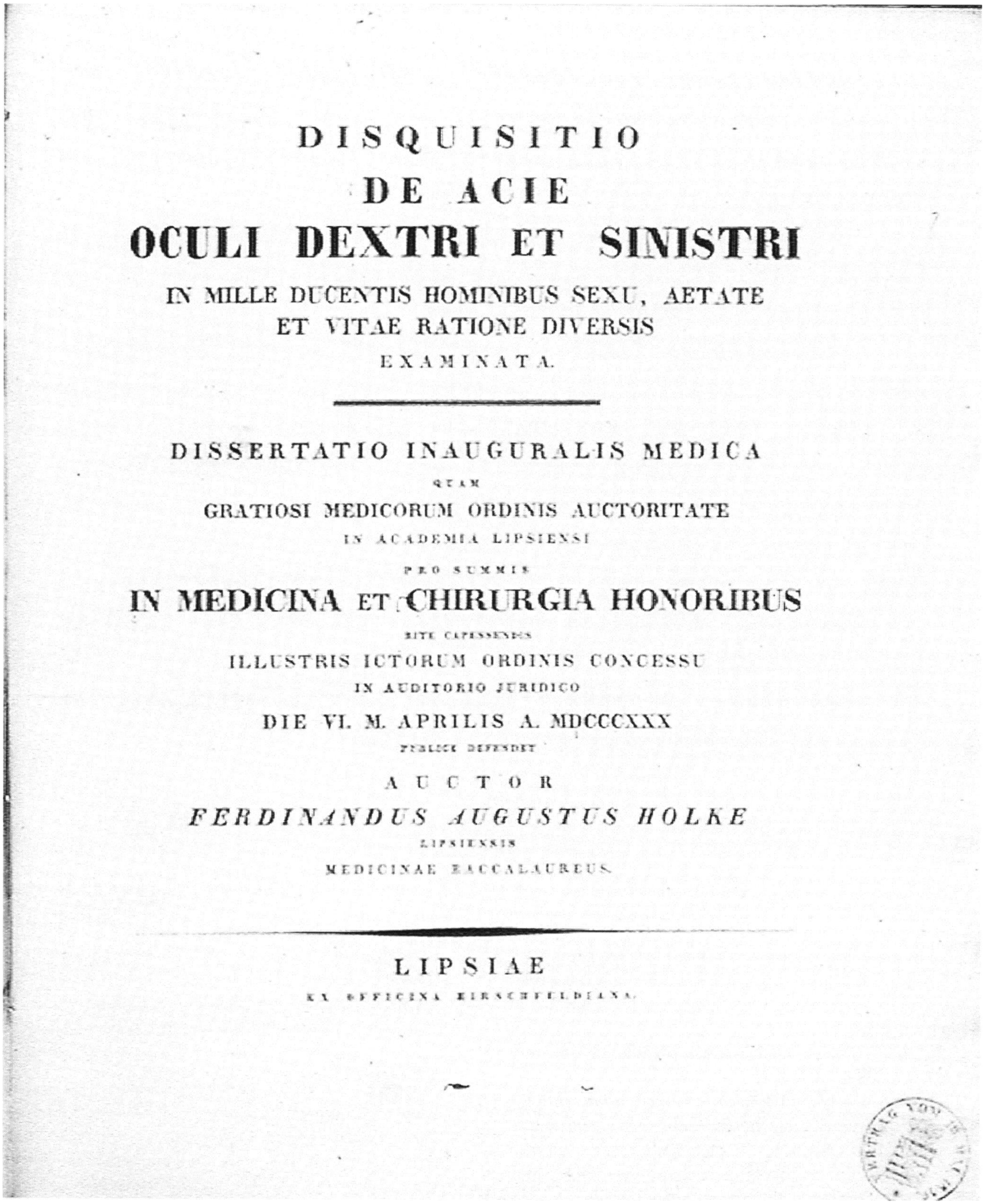
> An individual who is myopic, holds a book for reading, or anything that he may wish to examine minutely, much nearer to the eye than others; he cannot distinguish the countenances of performers on the stage, nor the details of pictures when placed some feet from him; he cannot read the inscriptions of doors and houses, nor recognize persons across the street; if he goes into a large room in which there are many persons he cannot readily distinguish those he knows.[36(p460)]

In 1835 or 1836, Küchler produced the first eye chart expressly designed to test visual acuity.[37] He cut small figures of people, cannons, guns, birds, farm equipment, dromedaries, and frogs from calendars and then glued these to paper in order of decreasing size. Küchler soon realized inherent problems with this test. He struggled with the lack of consistency and uniformity in difficulty of recognition of the various symbols. Küchler subsequently developed the first eye chart using words of different font sizes.

In 1838, Fleischman described a patient who slipped on the ice striking his head, leading to a large swelling the size of a fist above the right eye.[38(p88)] The patient subsequently sought medical advice because of his sensory perceptions, which were "rather thoroughly messed up." The patient was given an eye test and could read Cicero (pica, 12 point) type over a range of 5 inches to 3 feet with his right eye.[38(p90)]

In 1840, Frederick Tyrell described a boy 14 years of age whom he evaluated with acute-onset presbyopia. The patient could not read when ordinary print was placed at the usual reading distance from the eyes, and he was able to read common octavo print (small print) only with the assistance of a convex glass. His distance vision was not affected. His family doctor noted no improvement after a few days of treatment with leeches, blisters, purgatives, limited activity, and a moderate diet. Dr Tyrell recommended occasional counter irritation in the forehead by blisters, a plain diet, keeping the patient tranquil without exerting the organs unless a favorable change occurred. The boy recovered completely within 3 months.[39]

In 1841, M. Cunier described the results of an operation known as ocular myotomy to treat myopia. Four patients were freed from their infirmity by subconjunctival myotomy. Visual acuities were documented in 3 of the 4 patients. The first patient improved from seeing Double Cannon (large type) characters to Mignnone (small type). The second improved from myopia that was equal to blindness to being able to read Cicero (small type) characters at close proximity, at distance of 4 meters,

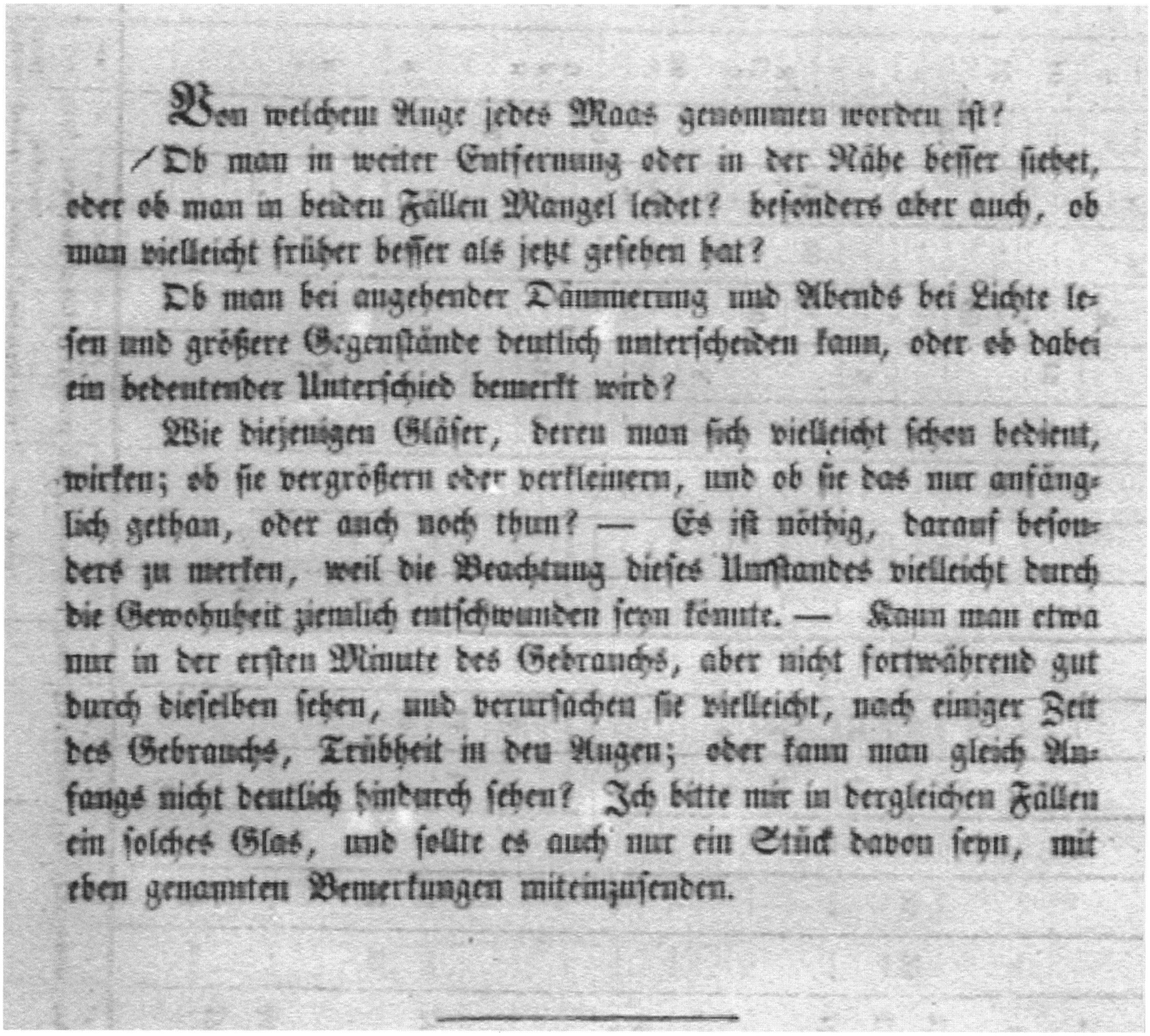


DISQUISITIO
DE ACIE
OCULI DEXTRI ET SINISTRI
IN MILLE DUCENTIS HOMINIBUS SEXU, AETATE
ET VITAE RATIONE DIVERSIS
EXAMINATA.

DISSERTATIO INAUGURALIS MEDICA
QUAM
GRATIOSI MEDICORUM ORDINIS AUCTORITATE
IN ACADEMIA LIPSIENSI
PRO SUMMIS
IN MEDICINA ET CHIRURGIA HONORIBUS
RITE CAPESSENDIS
ILLUSTRIS ICTORUM ORDINIS CONCESSU
IN AUDITORIO JURIDICO
DIE VI. M. APRILIS A. MDCCCXXX
PUBLICE DEFENDET
AUCTOR
FERDINANDUS AUGUSTUS HOLKE
LIPSIENSIS
MEDICINAE BACCALAUREUS.

LIPSIAE
EX OFFICINA HIRSCHFELDIANA.

FIGURE 9
Title page of dissertation by F. Holke 1830 entitled *Disquisitio de acie oculi dextri et sinistri in mille ducentis hominbus sexu, aetate et vitae ratione diversis examinata*, which contains, as an appendix, a reading test developed by Gottfried Tauber in 1816.



Von welchem Auge jedes Maas genommen worden ist?

Ob man in weiter Entfernung oder in der Nähe besser siehet, oder ob man in beiden Fällen Mangel leidet? besonders aber auch, ob man vielleicht früher besser als jetzt gesehen hat?

Ob man bei angehender Dämmerung und Abends bei Lichte lesen und größere Gegenstände deutlich unterscheiden kann, oder ob dabei ein bedeutender Unterschied bemerkt wird?

Wie diejenigen Gläser, deren man sich vielleicht schon bedient, wirken; ob sie vergrößern oder verkleinern, und ob sie das nur anfänglich gethan, oder auch noch thun? — Es ist nöthig, darauf besonders zu merken, weil die Beachtung dieses Umstandes vielleicht durch die Gewohnheit ziemlich entschwunden seyn könnte. — Kann man etwa nur in der ersten Minute des Gebrauchs, aber nicht fortwährend gut durch dieselben sehen, und verursachen sie vielleicht, nach einiger Zeit des Gebrauchs, Trübheit in den Augen; oder kann man gleich Anfangs nicht deutlich hindurch sehen? Ich bitte mir in dergleichen Fällen ein solches Glas, und sollte es auch nur ein Stück davon seyn, mit eben genannten Bemerkungen miteinzusenden.

FIGURE 10

Appendix fro dissertation by F. Holke 1830 entitled *Disquisitio de acie oculi dextri et sinistri in mille ducentis hominbus sexu, aetate et vitae ratione diversis examinata*, which is the vision test developed by Gottfried Tauber in 1816.

he could read shop signs, and he could recognize people at 30 paces. The third improved from being able to read large Cicero letters only to being able to recognize small Mignonne print.[40]

In 1843, Himley used a series of dots, crosses and numbers to assess vision.[41]

In 1843, Küchler introduced the first series of optometric scales specifically designed to test visual acuity (Figs 11 and 12). Because Küchler's vision test is the true starting point for all modern vision tests, this paper includes his discussion regarding the importance of this type of test in its entirety, this being the first time it has been translated into English. His comments are as important today as they were 158 years ago.

Schriftnummerprobe für Geifichtsleidende [Numbered Eye Chart, for the Vision Impaired] by Heinrich Küchler, Physician in Darmstadt.
Darmstadt: Johann Philipp Diehl, 1843.

[Foreword]
Since Valentin Hauy, we possess more or less practicable ways of making reading accessible to the blind. Quite apart from that goal, I will recommend below type samples for those who are going blind and whose visual ability the physician wishes to measure and, in the interest of curing, must measure.

[Main text]
All statements in case histories about the ability

to see have always been extremely vague and indefinite; the patients, they say, can read a coarser or finer print, can recognize the fingers, can make out large or small objects and this is the only introduction to evaluating visual ability found in published works and case histories. It is thus not only impossible for a third party to have even an approximate idea of a patient's degree of visual ability, but even the practicing physician frequently has no way of measuring this visual ability at various times. This all the more so, since generally during a single case history the objects used for testing are changed frequently, and since the light and weather conditions under which the vision test was done are often unknown.

Thus it is quite necessary that there should be a measure of a patient's visual ability which, extending to the finer nuances, is known to all colleagues in the field; for there are a great number of visual ability problems which lack any objective sign of illness, and where we must fall back on data of the increase or decrease in the patient's visual ability if we are to determine whether our diagnosis is correct and whether our proposed curative measures are appropriate. If these data cannot be measured exactly and cannot be compared precisely at various times, and if the physician can easily overlook slight deterioration of or improvement in the disease he is treating, then his evaluation of the ameliorative or harmful nature of his medicines will often suffer damaging delays; for the retina of the eye is so delicate that incorrect treatment cannot long be continued without the risk that incurable loss of sensitivity of this tissue will result.

For some time, therefore, I have, with great profit, made use of a "numbered eye chart" which is appended to this little work and which I recommend as a practical tool on the physician's work table or consulting desk, It has as its purpose:

1. To measure the patient's visual ability and, indeed, even to have a measure of this visual ability upon which all practitioners can agree.

2. To measure the visual ability of a single patient at various times and to have a measure of this ability, which is recognized by all practitioners.

The test will, however, if it is generally familiar and accepted, meet several secondary goals and help the practitioner out of many an embarrassment. Thus, for example, Beer says with respect to purchasing eyeglasses with cataract lenses from an optician in another location, one should measure precisely the size of the visible objects and the distance at which they can be seen and send these measurements to the optician, who can then determine the correct eyeglass number. How easy it is, however, to make a mistake in the extremely small measurements involved here; and how certainly these errors can be prevented with the aid of this numbered eye chart.

Instructions for using the chart are extremely simple and are, in the main, derived from the principles of common sense:

1. One must always have different print samples, or words and letters, in each size and alternate these in use.
2. One must be sure that all numbered eye samples are printed on identical white matte writing paper in exactly the same font and letter spacing.
3. One must have the print samples mounted separately on smooth cardboard.
4. One should always test the weakest eye first, and only in daylight.
5. During the test one should have the light fall somewhat diagonally from the side and in such a way that no dazzling or light loss is possible.
6. One must not fail to note in the patient's record any significant deviations in atmospheric weather or light conditions, as well as temporary physical conditions that might affect visual power.

If used in this way, I have no doubt that this numbered eye chart can achieve general application and use, and that the practicing physician will be richer by one further advantage in his trade.

Darmstadt,[42] December 20, 1842.

The 1854 edition of Lawrence's textbook, edited by Isaac Hayes, contains a description of a case, originally documented in the *Northern Journal of Medicine* by Dr James Hunter in May of 1845, of sudden and temporary presbyopia. A thorough assessment of visual acuity is included in the evaluation as follows:

> To ascertain the state of this sight, Dr Hunter gave him a printer's specimen sheet, containing a series of paragraphs in all the various sizes of a book type, from English to Nonpareil and the smallest, Diamond. He could read the English type, though not fluently, and saw it best at 11 inches from his eye. Of the paragraph printed in Pica No. 1, he could only make out a word here and there. The paragraph Pica No. 2 was almost quite illegible, and the smaller sizes of type could not be read at all. Directing his attention to a dark green stable-door in my back garden, he could distinguish the key-hole, which was 2 inches long by

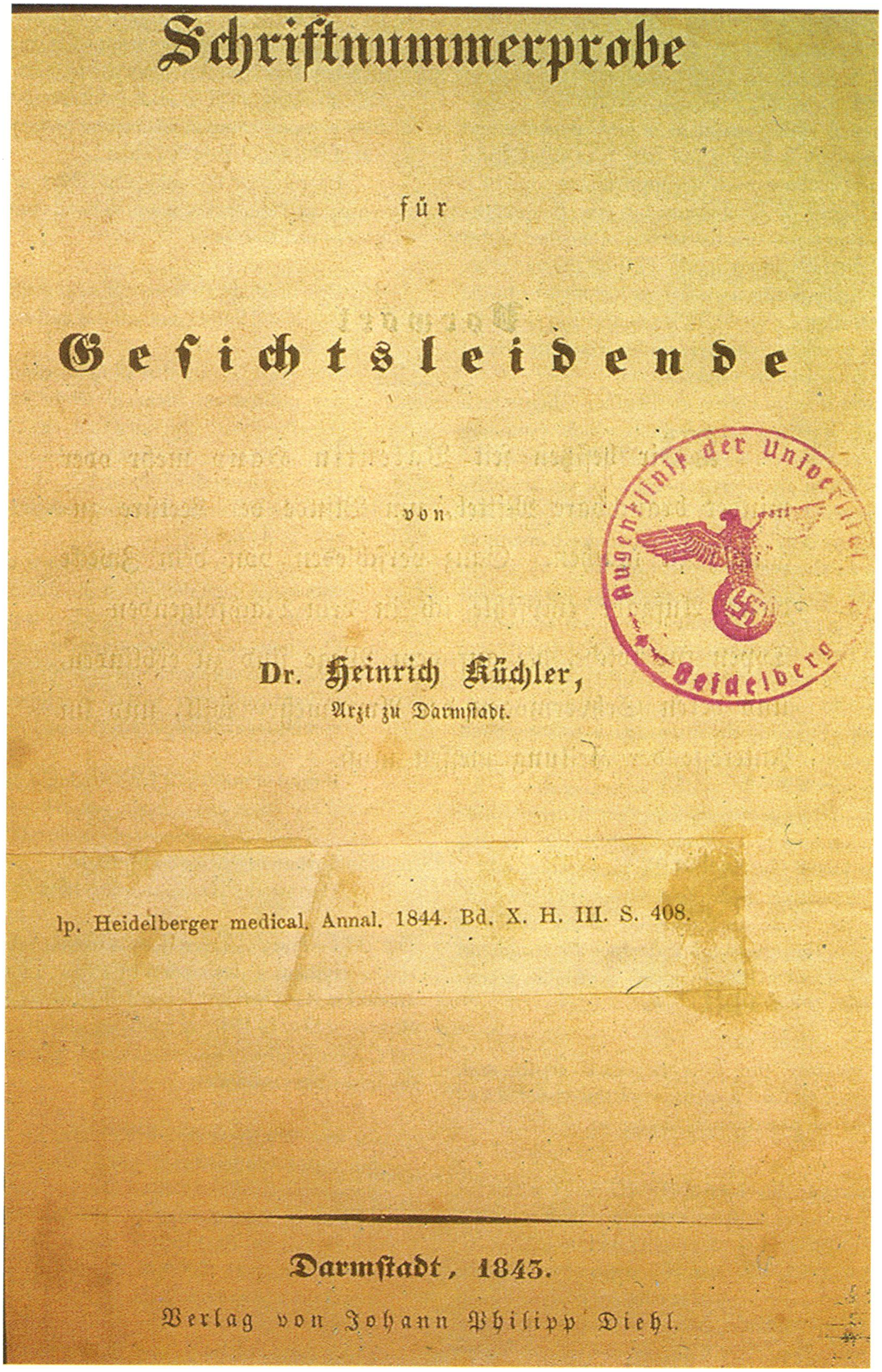


FIGURE 11
Cover of first eye test printed specifically to test visual acuity. Booklet is entitled *Schriftnummerprobe für Gefichtsleidende* [Numbered Eye Chart for the Vision Impaired] and was prepared by Heinrich Küchler in Darmstadt, Germany, in 1843.

FIGURE 12

First eye test printed specifically for testing vision. It was developed by Heinrich Küchler in Darmstadt, Germany, and was published only once.

five-eighths of an inch wide, the distance being 71 feet; but he could not see some black iron spikes about 7 inches long and probably one-sixth to one-fifth of an inch in thickness, in a dovecote at a distance of nearly 78 feet; but which even to a good eye were not perceptible, from their being in contrast with a slated roof. Convex lenses improved his sight much, so that he could read any size of type, from the largest to Brevier No. 1 inclusive. With a pair of 10 inches focus he could read Minion No. 1. With a pair of 9 inches he could read Nonpareil No. 2 and even a few words of a still smaller type, Diamond, though with difficulty... Still, he could not count a series of black spots 0.007 of an inch in diameter, placed on a white background, without using a glass of 6 inches focus, and with this again he could not see ordinary sized type so distinctly as with glasses of 9 inches focus.[43]

In 1854, Eduard Jaeger Ritter von Jaxtthal introduced his *Schrift-Scalen*, or Test-Types.[44] The initial printing of the eye test was included as an appendix to his book entitled *Ueber Staar und Staaroperationen nebst anderen Beobachtungen und Erfahrungen* [On Cataracts and Cataract Operations Together With Other Observations and Experiences]. Subsequently, 9 freestanding editions of his eye test were published resulting in a total of 10 standard editions from 1854 through 1909. Jaeger included a description of his test, how it was to be used, and its significance with the initial printing. The first English translation of this section of his book is included herewith. His comments provide a great deal of insight into Jaeger and his eye test.

Testing Visual Acuity In Healthy and Diseased Patients

With the intention of developing a precise practical scale for testing the visual acuity of healthy and diseased patients which would be understood even by poorly educated patients, I selected type sizes from the same typeface in such a way that the letters increase in the most even possible ratio from the smallest to the largest.

The results of examinations with this print scale have been published in the hope of providing data for the degree of visual affection by various illnesses, for the influence of the various organs of the eye on the act of vision, as well as to determine the value of cataract operations and assess the various methods of cataract surgery.

Since such vision testing provides precise and reproducible results only when the examination is performed under similar circumstances, and since some other eye doctors might be inclined to undertake similar studies, these print scales have been included in an appendix herewith.

The use of these type scales as a method of testing vision offer many advantages to both physicians and opticians for the accurate prescription of eyeglasses. These print scales have been produced in German, French, and English in order to attain the greatest possible use.

The patient is asked to hold the print scales in his hands and attempt to read moderately large print in his customary manner so as to determine in general what manner, posture, and distance he had accustomed himself to read in.

The patient's best visual acuity is determined by asking the individual to select the smallest print that can be read with moderate fluency. The greatest distance at which this occurs is then recorded.

For most of these tests, it is quite sufficient to read 1 or 2 lines, but if the test is to be repeated 2 or 3 times with the same size type, then the subject must start with a different line each time lest he deceive himself and others by half guessing at what he has already read.

The subject holds the book in his hands to test near vision. For testing distance vision, the chart is fastened to a wall in a suitably bright part of the room at eye level or slightly below.

For greater distances, I used signs posted on the building across the street, at 35 feet, directly across from my window. These signs consist of dull gold letters on a black background. The letters in the larger print are 9 Viennese inches high and 11 inches thick; the smaller ones are 2 inches high.[44]

CHRONOLOGY OF JAEGER'S TEST-TYPES (TABLE I)

The first edition of Eduard Jaeger's Test-Types was published in Vienna in 1854 by the Staatsdruckerei and distributed by L.W. Seidel. The typefaces ranged in size from N1 to N20. In addition to the Test-Types, the book also contained a linear vision scale that resembles a picket fence approaching the horizon. The lines get much smaller and closer together as one looks across the page from left to right (Fig 13). This vision test, which was adapted by Eduard Jaeger from a scale developed by Professor S. Stampfer to test the optics in telescopes,[45] was included as an objective test of visual acuity. Jaeger thought that this linear scale was more precise than using either letters or text. However, it was likely abandoned because it was difficult to administer. Jaeger described his linear scale for testing visual acuity as follows:

> Although using type scales to determine visual acuity offers sufficient precision for practical purposes, I have nevertheless recently used an additional method to obtain the greatest possible precision.
>
> For this purpose I selected a scale of black strokes on a white background, decreasing in a certain ratio in size and distance from one another, similar to that which was proposed years ago by Professor Stampfer for testing the quality of telescopes, produced by Voigtländer the optician.
>
> Resolution is to be understood such that the white space before the indicated black stroke can still be separated with certainty, even though one is not able to count the black strokes up to this point with certainty.
>
> According to these findings, an eye, which can resolve the stroke scale down to the 80th stroke, must be regarded as good and sharp. Particularly good, strong eyes can resolve 3 to 5 additional strokes; the maximum was 6 to 7 strokes beyond the limit of this scale. This difference between eyes remains at all distances.[44(pp112-115,128)]

The first edition of Jaeger's Test-Types was published in German, French, and English. The German version was printed using Walbaum Fraktur, the French and English were printed using modern Bodoni.

The first independent edition of Jaeger's Test-Types was published in 1857, and was known as the Second Edition. It was also published in Vienna, by the *kaiserlich-königlichen Hof und Staatsdruckerei*, the state printing house. Before the dismantling of the monarchy in Austria, most government institutions were referred to as imperial; therefore, the state printing house was called the Imperial Printing House. L.W. Seidel, in Vienna, commissioned this booklet. In addition to being printed in the 3 primary languages of German, French, and English, this edition also contained text in Italian, Dutch, Hungarian, Bohemian (formerly a province of Western Czechoslovakia), Russian, Greek, and Hebrew. The German, French, and English text was printed in letter sizes from N1 to N20. The text in Italian, Dutch, Hungarian, and Bohemian was printed in font sizes N1, 3, 5, 7, 9, 11, 13, 14, 16, 18, 19, and 20. In Russian, the letter sizes were printed in N3, 5, 10, 13, 16, 17, 18, and 20. The Greek text was printed in sizes N4, 6, 9, 13, 15, 18, 19, and 20. Hebrew was printed in letter sizes N5, 6, 10, 13, 15, 17, 18, and 20. This edition did not contain a linear scale. The title page in this edition simply notes the

TABLE I: CHRONOLOGY OF JAEGER'S TEST-TYPES (*SCHRIFT-SCALEN*)*

EDITION	YEAR	LANGUAGES	NO.	LINEAR SCALE	MUSIC STAVES	PUBLISHER
1st	**1854**	**Ger/Fre/Eng**	**1-20**	**Yes**	**No**	**Vienna**
2nd	**1857**	**Ger/Fre/Eng(& others)**	**1-20**	**No**	**No**	**Vienna**
3rd	**1860**	**Ger/Fre/Eng**	**1-20**	**Yes**	**No**	**Vienna/Paris**
	1862	Spanish				Vienna/Paris
	1862					Portuguese
	1863	Ger/Fre/Eng	21-24			Vienna/Paris
	1864	Rus/Ita/Greek/Heb				
Pocket	1865	Ger/Fre/Eng	1-24	No	No	Vienna
	1866	Ger/Fre/Eng	21-24	No	Yes	Vienna/Paris
4th	**1867**	**Ger/Fre/Eng**	**1-24**	**Yes**	**Yes**	**Vienna/Paris**
1st (USA)	1868	English	1-20	No	No	New York
5th	**1874**	**Ger/Fre/Eng**	**1-24**	**Yes**	**Yes**	**Vienna/Paris**
6th	**1878**	**Ger/Fre/Eng**	**1-24**	**Yes**	**Yes**	**Vienna/Paris**
7th	**1882**	**Ger/Fre/Eng**	**1-24**	**Yes**	**Yes**	**Vienna/Paris**
8th	**1887**	**Ger/Fre/Eng**	**1-24**	**Yes**	**Yes**	**Vienna/Paris**
	1895	Czech	1-24	No	Yes	
Modified	1895	German	1-16	No	No	Vienna
9th	**1896**	**Ger/Fre/Eng**	**1-24**	**Yes**	**Yes**	**Vienna**
10th	**1909**	**Ger/Fre/Eng**	**1-24**	**Yes**	**Yes**	**Vienna**
	1924	Czech	1-24	No	Yes	

* All standard editions (in bold) are virtually identical, including text, type sizes, and typefaces.

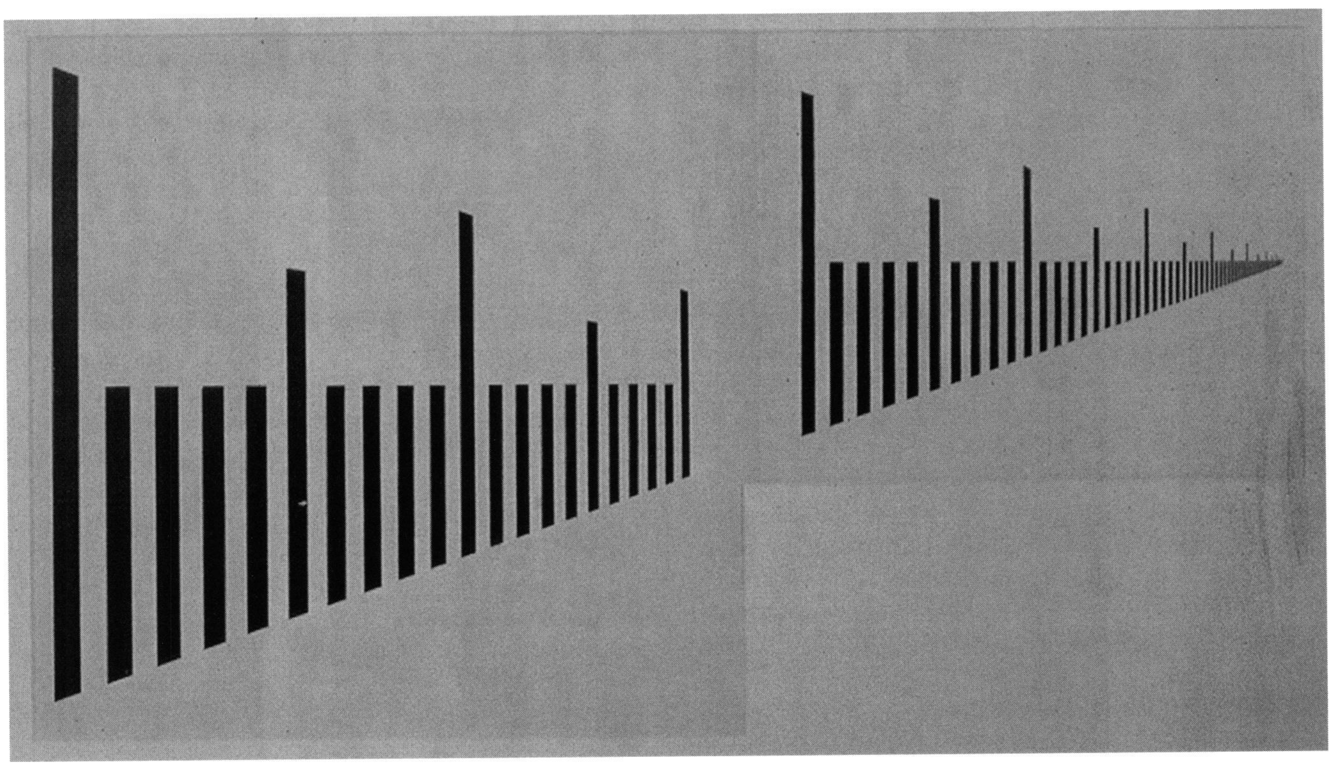


FIGURE 13

Eduard Jaeger's linear vision test consisting of series of lines that decrese in size geometrically from width of 0.4597 inch (No. 1) to width of 0.0037 inch (No. 80). Measure of vision was determined by ability of patient to be able to resolve black lines from white interspaces. An eye with normal acuity sees No. 5 at 100 feet, No. 30 at 20 feet, and No. 80 at 1 foot. All measurements are in Viennese inches or feet. Careful measurements using this scale allowed Jaeger to determine the limit of normal vision to be approximately one minute of arc.

book as *Schrift-Scalen des Prof. Jaeger Jun, zweite vermehrte Auflage* [second enlarged edition].

In 1860 Jaeger produced the third edition, which was more widely distributed. It is the edition commonly found in libraries throughout the world. This edition is entitled *Schrif-Scalen* by Professor von Jaeger, Jr. It was printed by *kaiserlich-königlichen Hof und Staatsdruckerei* in commission of L.W. Seidel in Vienna. This edition was simultaneously printed in Paris. The cover of the Paris edition is designated as follows: *Échelles de Caractères D'Impression par la professor E. de Jaeger, fils*. This third edition is noted as being printed in Vienna by the *Imprimerie Impériale et Royale de la cour et de L'état, librairie de* L.W. Seidel and in Paris by Victor Masson. This edition, which was printed in German, French, and English only, saw the return of the linear scale. Also, the type sizes were produced in N1 through N24, rather than the standard N20 that Jaeger had used up to that point.

A Spanish edition, entitled *Escala de Numeros del Professor de Jaeger, Jr.* was printed in 1862. It was distributed by L.W. Seidel in Vienna and by Victor Masson in Paris. The type sizes in this text are designated from numbers N1 through N24, the text is in Spanish only and the font is Bodoni. This edition was evaluated at the University of Vienna library. Its call number is I156867. The call number for the same text at the Austrian National Library in Vienna is 64237-B. A Portuguese edition was also published in 1862.

In 1863, Jaeger published a supplement for his Test-Types. This supplement contained the 4 larger font sizes, which were missing from the first 2 editions (1854 and 1857) (ie, N21 through N24). This may have been added at the urging of Donders, who used Jaeger's larger letters to test distance vision. The 1863 supplement was evaluated at the National Library of Medicine, History of Medicine Division, in Bethesda, Maryland. Its call number is WW J22s 1860 supplement. The cover of this reads *Nachtrag zur dritten Auflage*, [supplement to the third edition], *der Schrif-Scalen* von Professor von Jaeger, Jr. This supplement was published in Vienna by *kaiserlich-königlichen Hof und Staatsdruckerei* in commission by L.W. Seidel and also in Paris by Victor Masson. This supplement contains text in English only; however, it is likely that the text in both French and German exist elsewhere.

In 1864, several freestanding second editions of Jaeger's Test-Types were printed in Russian, Italian, Greek, and Hebrew. Although these editions have not been directly evaluated, their existence is documented in an advertisement for these Test-Types on the envelope containing the 1865 English pocket edition of Jaeger's Test-Types. It would seem likely that first editions in these languages were also printed; however, the multilingual second edition printed in 1857 may represent the first edition.

In 1865, Jaeger published a pocket edition of his Test-Types in the 3 primary languages, German, French, and English. Both a German and an English edition have been evaluated. The title pages of these editions read as follows: Scrift-Scalen, by Eduard Jaeger Ritter von Jaxtthal, doctor, professor and ophthalmic surgeon to the Imperial Royal General Hospital &c. &c. [etc., etc.]. The pocket editions were printed by the Imperial Royal Court and State Printing Establishment in Vienna and distributed by L.W. Seidel and son. This pocket edition is located at the National Library of Medicine, History of Medicine Division, Bethesda, Maryland. Its call number is WW J22s 1865. The other pocket edition that was evaluated is a German edition located in the Snellen and Donders Museum and Library in Utrecht, Kingdom of the Netherlands. The shelving number of this book is 494.

The pocket vision test is interesting because it contains several unusual items. First of all, the booklet slides into a small case, which also contains a pencil and a ruler. The brass-folding ruler is designated in Viennese inches on one side and in centimeters on the other side. Viennese inches were not the same size as the modern inch (1 Viennese inch=1.037 imperial inches or 2.634 cm). The first few pages of the booklet contain tables that provide the metric equivalents for numerous inches used throughout the 19th century world.[1] By providing this information, Jaeger made it possible to measure and compare the visual acuity of patients across the globe. Jaeger's tables provide measurements used by 60 different states and towns. The introductory statement included with his pocket vision test demonstrates his awareness of the problems encountered measuring visual acuity in the premetric world:

> Wishing to facilitate the use of my type scales for medical practitioners by enabling them to conveniently carry about with them everything which is necessary for determining the visual power and refraction of the eye, as well as noting the results therefore, I have caused these scales to be published in a portable form, and a copy to be furnished with an inch rule, a pencil, and a parchment leaf. It will be found to reduce the measures adopted on a scale of the accompanying inch rule to any other current measure by following the indications given in the adjoining list, where the Vienna inch and centimeter are compared with the 24 other scales.[46(pp2-6)]

The type is numbered from N1 through N24, and is printed using a Fraktur font for the German *Schrift-Scalen* and using a Bodoni font for the English test. None of the pocket editions contains a linear scale. The complete unit fits easily into a shirt pocket and has the appearance of a work of art rather than a portable eye test. In 1892, Schneller developed a similar pocket eye test to replace the "Little Jaeger," which had "vanished from the book market."[47]

The 1866 edition is similar to the 1863 edition. It is a supplement to the third edition, entitled *Nachtrag zur dritten Auflage der Schrift-Scalen* von Professor Eduard Jaeger, Ritter von Jaxtthal, published in Vienna, by *kaiserlich-königlichen Hof und Staatsdruckerei* and in Paris by Victor Masson. This edition contains large N21 through N24 type only and is printed in German, French, and English. In addition, music staves are included in the booklet. This is the first time staves of music were included in the eye test. The staves are printed in 5 sizes, increasing from numbers No. 1 through No. 5. The selection of music is the adagio movement of Beethoven's Sonata 17 in D minor, Opus 31, No. 2, which was originally published in 1802. It is also known as the "Tempest Sonata." The end of the booklet includes a linear scale. The 1866 edition was examined at the University Library in Vienna.

A wooden "rolling pin" edition of Jaeger's Test-Types was produced circa 1866 (Fig 14). The original instrument resides in the Museum of the Pennsylvania Hospital in Philadelphia. At least 49 copies of this device were produced by the medical division of Sharp & Dohme. No reference to this unique vision-measuring device has been discovered in the literature. It was evaluated by George Griffenhagen, Acting Curator, Division of Medicine and Public Health, United States National Museum, Smithsonian Institution in Washington, DC, who concluded that the text was likely a translation from an unspecified foreign language into British English. The text is labeled .25M, .37M, .50M, .75M, 1M, and 1.50M. The supposition that this instrument was produced by Snellen, or 1 of his associates, is suggested by the following:

- Snellen M units are used without any mention of Jaeger's N units
- Snellen was very comfortable with English and often communicated with his sister who resided in London using this language
- The text discusses accommodation of the optical system of the eye, and Snellen's mentor Donders was a pioneer in this area of ophthalmology
- The dating of the instrument by the Smithsonian curator places it into the correct time period.

The mystery regarding this instrument remains unsolved.

The 1867, 4th edition of Jaeger's Test-Types returns to the standard format. This edition is entitled Schrift-Scalen by Professor Eduard Jaeger Ritter von Jaxtthal, published by *kaiserlich-königlichen Hof und Staatsdruckerei*, in commission of L.W. Seidel & Son in Vienna and Victor Masson in Paris. This copy was obtained from the University Library in Vienna. Its call number is I134053. This edition was published in the 3 primary languages of German, French, and English; type sizes N1 through N24. It also contains music staves No. 1 through No. 5 and includes the linear scale.

The first American edition of Jaeger's Test-Types appeared in 1868. This is the only freestanding edition ever published in the United States. The cover of this edition reads *Test-Types for the Determination of Acuteness of Vision, Myopia, Range of Accommodation, etc., corresponding to the Scrift-Scalen of Eduard Jaeger, Professor in the Imperial Royal University of Vienna*. William Wood & Co published this edition in New York. William & Wilkins purchased William Wood & Co in 1932. The size of the text ranges from N1 to N20. The fonts used to print this edition were significantly different from any previous edition of Jaeger's Test-Types, including the standard editions printed in Vienna. The typeface is similiar to a Primer or Century font and appears consistent until N14, at which point it changes to a bold typeface. At N18 another unique typeface is introduced, which may be a Boton or possibly Clarendon font. N19 marks the introduction of yet another completely different typeface, which is similar to a Tower font. The final typeface in this Test-Type, N20, is similar to the standard Jaeger Bodoni used to print Jaeger's Test-Types in Vienna. The 1868 American edition is located in the National Library of Medicine, Bethesda, in the History of Medicine Division; the shelving number is 7309, Box No. 106. An inscription on the inside cover states that it was given to Charles H. Crane, the Assistant Surgery General of the United States, with the compliments of the publisher.

The independent 1868 edition of Jaeger's Test-Types was not reprinted freestanding; however, it was included unaltered as an appendix in an ophthalmology textbook also published by William Wood & Co. The book is entitled *A Treatise on the Diseases of the Eye, including the anatomy of the organ* by Carl Stellwag von Carion, MD, Professor of Ophthalmology at the Imperial Royal University of Vienna, translated from the third German edition and edited by Charles B. Hackley, MD, and D.B. St John Rossa, MD. Two other editions of this book were published in 1870 and 1873. The 1870 printing was the second American edition of this book. The title, authors, and publisher remained unchanged. The 1873 edition included one additional author, Charles E. Hackley, MD, and was designated the fourth revised and enlarged

FIGURE 14

Wooden "rolling pin" edition of Jaeger's Test-Types. There is no documentation of this device in the literature. The instrument has been dated circa 1866 by the Smithsoniam Institute in Washington, DC.

edition. This appears to be the third American edition, which was translated from the fourth German edition.

Another modified version of Jaeger's Test-Types was published in the United States in 1875. This version was included as an appendix in a book entitled *Vision: Its Optical Defects and the Adaptation of Spectacles with selections from the Test-Types of Jaeger and Snellen* by C.S. Fenner, MD, published by Lindsay & Blankiston in Philadelphia. This version of Jaeger's Test-Types contains font sizes numbered N1, 2, 4, 5, 7, 11, 13, and 14. The actual corresponding font sizes when compared to any of the US editions published by William Wood & Co, are as follows (Fenner=Wood): N1=N2, N2=N3, N4=N4, N5=N6, N7=N7, N11=N11, N13=N12, and N14=N14.

The next edition, the 1874 fifth edition, was published in Vienna and Paris in German, French, and English. It included type sizes N1 through N24. This edition also included music staves numbered 1 through 5 and a linear scale. The cover of this edition is labeled as follows: *Schrift-Scalen by Dr. Eduard von Jaeger* (the titles of Professor and Ritter von Jaxtthal were not included). This edition was also published by *kaiserlich-königlichen Hof und Staatsdruckerei* and distributed by L. W. Seidel & Son in Vienna and by Victor Masson in Paris.

The sixth edition, published in 1878, is virtually identical to the fifth edition. This edition was examined at the Institute of History of Medicine in Vienna. Its catalog number is 32.178.

The seventh edition, published in 1882, is identical to the sixth edition. This edition was obtained from the University Library in Vienna. Its catalog number is I134051.

The eighth edition was published in 1887. This edition is nearly identical to the 1882 printing with a few minor exceptions. This edition was not published in Paris, and the music staves are missing; however, it does contain the linear scale. The title page reads as follows: Vienna, distributed by L. W. Seidel & Son, *K.K. hofbuchhändler* printed by *kaiserlich-königlichen Hof und Staatsdruckerei*. This edition was also published in 3 languages, German, French, and English in font sizes N1 through N24. This edition was also examined at the University Library in Vienna, catalog number I23612.

Several modified editions of Jaeger's Test-Types were printed in 1895, no standard editions. The most important of the altered versions is the one modified by Ernst Fuchs, which is entitled *Leseproben für die Nähe*, Jaeger's Schrift-Scalen modified by Professor Dr E. Fuchs published in Vienna by *F. Fritsch K. und K. Hof und Universtates Optiker. VIII, Alserstrasse No. 17, Buch und Kuns key drekiei "steyremuhl,"* Vienna, 1895. This Test-Type booklet was published only in Vienna, only in German, and only in 1895; however, 2 editions of this work were printed that year. One copy of the first edition was obtained from the University Library in Vienna, call number: I190242. The other first edition and the second edition were both obtained from the Austrian National Library in Vienna. The call number of the first edition is 197720B, and that of the second is 84.099C. The second edition is identical to the first edition with the exception of it being labeled "Second Edition." The contained Test-Types are numbered from "Nr. 1" to "Nr. 16" only and include a table that gives measurements of the letter height and distance in centimeters at which the lower case letter "i" subtends 5 minutes of arc. Fuchs finally provided this missing data for Jaeger's Test-Types (ie, the Snellen equivalent or distance at with the letters would subtend 5 minutes of arc). This was a problem that Snellen had with Jaeger's type, which "Fuchs was kind enough to correct."[2] However, in producing a modified version of Jaeger's classic Test-Type, Fuchs completely altered the vision test, making it much less acceptable to patients.

A freestanding Bohemian (Czechoslovakian) edition entitled *Optotypy* by Eduarda Jaegra z Jaxtthalu, was also published in 1895. This edition appears to have been translated by Professor Doctor Schöbl. The publisher is v Lipsku a ve Vídni, Nákladen knihkupectví Frant. Deuticke, publication number 438. The type is numbered 1 through 24, and the font resembles Bodoni. This edition contains a set of music staves, No. 1 through No. 5; the linear scale is not included. This edition was obtained from the University Library in Vienna, and its call number is I167666.

In 1896, the ninth standard edition was printed. This edition is entitled *Schrift-Scalen des Dr. Eduard von Jaeger*, ninth edition, Vienna, 1896, published by L. W. Seidel & Sons, *kaiserlich-königlichen Hofbruckhändler, Aus Der K.K. Hof und Staatsdruckerei*; and is labeled identically to the 1887 edition. The 1896 edition includes the 3 primary languages, German in the Fraktur, French, and English in Bodoni, numbers N1 through N24 in each language. It also includes the music staves, No. 1 through No. 5, and the linear scale. This edition is located at the University of Vienna Library, call number, I197012.

The final standard edition was printed in 1909. This edition was also entitled *Schrift-Scalen des Dr. Eduard von Jaeger*, tenth edition, Vienna, published by L.W. Seidel & Sons, *K.K. Hofbruckhändler*, and printed by *kaiserlich-königlichen Hof und Staatsdruckerei*. This edition includes the 3 primary languages, German in the Fraktur font, French, and English in Bodoni, numbers N1 through N24 in each language. It also contains the music staves, No. 1 through No. 5, and includes the linear scale. This edition is available at the University of Vienna Library and the Royal Society of Medicine library in London.

The final copy published is Czechoslovakian and is entitled *Optotypy* by Jaeger Eduarda Jaegra z Jaxethelu. It was published in 1924. The front plate of this edition is identical to the first freestanding Czech version published in 1895. This copy was evaluated at the Austrian National Library in Vienna; call number: 606680-B. The text is in Czech numbered from 1 to 24, and the font is Bodoni. This version of Jaeger's Test-Type contains 5 staves of music and no linear scale.

All 10 standard editions of Jaeger's Test-Types have one unifying theme: uniformity and consistency. These editions are as follows: (1) 1854, (2) 1857, (3) 1860, (4) 1867, (5) 1874, (6) 1878, (7) 1882, (8) 1887, (9) 1896, and (10) 1909 (Table I). All of these editions were published in at least the 3 primary languages of German, French, and English. The font type and size remain consistent throughout, with few exceptions. All of the German text was printed using Walbaum Fraktur,[48(p46)] and the French and English were published using Bodoni.[48(p20)] All of these editions consisted of at least N1 through N20 (most contained N1 through N24) for all 3 primary languages, German, French, and English. A supplement of containing N21 through N24 was published in 1863 and 1866. The only editions missing these 4 large fonts are the first edition of 1854, the second edition of 1857, which was printed in numerous languages, and the fourth edition of 1867. Most editions included Jaeger's linear vision scale and 5 different sizes of music staves, numbered No. 1 through No. 5.

Few inconsistencies exist in Jaeger's 10 standard editions of his Test-Type. The font and print sizes in the German text are identical throughout the 10 editions. The German text for type sizes N1 and N2 in editions 1, 2, and 3 is different in content from all other 7 editions. It appears as if this was done mainly to break the text into short passages, placing dashes between sentences and phrases, to make it easier for the patient to read a line of text and also easier for the examiner to follow along with the patient. The text used in the original paragraph for N1 was written by Johann Gottfried Herder (1744-1803) and the text in the "updated" version of N1 was taken from a literary work by Johann Wolfgang von Goethe (1749-1832), who is said to have been the German equivalent of William Shakespeare. The text from both the original and updated N2 was taken from the various writings by Friedrich Schiller (1759-1805).

The French and English fonts and text in the second through the tenth editions are virtually identical. The first edition of Jaeger's Test-Types has a few inconsistencies when compared with all other standard editions. These exceptions are minor and do not carry over to the second through tenth editions. N13 and N14 have the same letter height as all other editions, but the letters are slightly thicker (not condensed). N15 is slightly smaller and thicker (not condensed), N16 and N17 are identical, N18 is larger and thinner (condensed), N19 and N20 are identical in terms of both font and letter size; however, the text is slightly altered (ie, either different in content, out of order, or both).

There are a few variations in spelling and capitalization from edition to edition in Jaeger's Test-Types. These appear to have been kept to a minimum. There is also some degree of variability in letter spacing and less so in line spacing of the text, which becomes much more uniform as the editions progress.

The fonts in Jaeger's *Schrift-Scalen* were compared with those contained in a book entitled *Schrift-Proben* [Type Specimens], which is the printers catalogue of type specimens from the *kaiserlich-königlichen Hof und Staatsdruckerei* in Vienna in 1868. This book contains the fonts that were available in 1868 from the print house in Vienna that produced all of the standard editions of Jaeger's Test-Types. The first 20 fonts, N1 through N20 of the Fraktur, are identical to those used to print Jaeger's German text, number for number. It is therefore likely that Jaeger chose his type samples "off the shelf" and simply used the print house's designation for the type sizes to designate his letter sizes. The larger fonts, N21 through N24, are significantly smaller than those used by Jaeger, which may partly explain why the earlier editions of his Test-Types did not contain the larger font sizes. Unfortunately, many of the documents relating to the 19th century font library at the *Staatsdruckerei* in Vienna were destroyed during World War II, leaving many questions unanswered.

ORIGINS OF MODERN OPHTHALMOLOGY

Modern ophthalmology began in Vienna during the reign of Empress Maria Theresa (1717-1780). Maria Theresa, the Holy Roman Empress, queen of Hungary and Bohemia and archduchess of Austria, was responsible for major social reforms, including public education, and believed strongly in stratified universal education.[49] The Vienna medical school was reorganized under her rule. She had 16 children, one of whom was Marie Antoinette. Her son, Emperor Joseph II (1765-1790), established the *Josephinische Militärakademie* in 1785 to transform surgery from a trade learned by apprenticeship into an academic discipline similar to medicine.[50] The Emperor did this in order to provide his solders with the best possible medical and surgical care if they were wounded in battle. The building that housed this newly formed institute is the current home of the Institute for the Study of the History of Medicine in Vienna and is featured on the 50-shilling Austrian bank note. The newly established institute experienced early growing pains, was completely reorganized in 1796, and was thereafter known as the *Medicinisch-Chirugischen Josephs-Akademie.*[50] Friedrich Jaeger, Eduard's father, held the chair in ophthalmology at the Medico-Surgical Joseph's Academy from 1826 until 1848, when the institute closed.[51]

A chance occurrence set into motion a series of events that ultimately culminated in the development of ophthalmology as an academic surgical discipline. Countess Sylvia Tarouca, one of the favorite court ladies of Empress Maria Theresa, became blind rather suddenly. The Empress summoned her best medical practitioners, who could not agree on a diagnosis and appropriate treatment. Some felt that the countess had cataracts, which would require surgery; others felt that she was incurably blind from amaurosis. Not wanting to risk surgical treatment unnecessarily, Michael Johann Baptist von Wenzel (d. 1790), a famous itinerant cataract coucher of German birth who lived in Paris, was summoned for another opinion.

At that time, cataract surgery was performed exclusively by itinerant cataract couchers, the most notorious of whom was the Chevalier (John) Taylor. John Taylor was not a typical itinerant eye surgeon in that his father was a general surgeon, and John Taylor undertook medical studies at St Thomas' Hospital in London, where he became medically qualified.[52] Taylor performed unsuccessful cataract surgery on J. S. Bach and is said to have been responsible for shortening Bach's life. Although Taylor had formal medical training, he lacked the surgical skills of Wenzel, who may have studied under Taylor.

Most cataract couchers of that day had no formal medical training. They were merely a group of itinerant charlatans who toured through most of Europe (often accompanied by monkeys) shamelessly advertising, self-promoting their talents, pedaling eye salves and washes, and couching cataracts.[52] Most reputable medical practitioners were reluctant to pursue this area of surgery because of its association with quackery and also because couching had limited results: Often vision was immediately improved using these techniques, but the long-term results (days later) were often disastrous. Cataract surgery–couching–was therefore performed by itinerant practitioners with their lack of scruples and "here today, gone tomorrow" mode of operation rather than by local practitioners who had to live with the long-term consequences of their surgery.

Nonetheless, some traveling cataract surgeons developed a great deal of skill and became highly sought after, particularly by European royalty in whose circles they attempted to ingratiate themselves. The Baron Wenzel was such a surgeon. His son, Jacob de Wenzel, who often accompanied and assisted him, eventually received a medical degree from the *Paris Faculté* and became the ophthalmologist to the imperial family in Paris.[53] After arriving in Vienna, Baron Wenzel correctly diagnosed the Countess Tarouca's cataracts, successfully operated, and restored her vision. Because it had been a long and costly journey for Wenzel, the empress paid him 1,000 florins to come to Vienna and gave him in addition a ring worth 6,000 florins to stay and teach her doctors cataract surgery.

Joseph Barth (1743-1818), the professor of anatomy and physiology at the University of Vienna, was Wenzel's most prominent pupil. However, Barth was anxious to return to his work in anatomy and physiology and therefore taught what he had learned about cataracts to his assistant, Georg Joseph Beer (Eduard Jaeger's maternal grandfather). Beer's skills soon surpassed those of Barth, and Beer ultimately became one of the most famous ophthalmologists of his day. He went on to hold the first university chair of ophthalmology in the world. The government set aside 20 beds in the general hospital for ophthalmology and made Beer the head of this unit in 1812. In 1818, he became full professor (Ordinarius) of ophthalmology at the University of Vienna.[54] Friedrich Jaeger, Eduard's father, became Beer's assistant and in 1815 married his daughter. Friedrich Jaeger became the most exceptional eye surgeon of his day. His students included Albrecht von Graefe and his son Eduard.

THE JAEGER DYNASTY

Eduard Jaeger was a member of the first dynasty of ophthalmology the world has known. With his death, the dynasty ended (Fig 15). Neither of his children became physicians. His daughter married an attorney, and his son turned toward technical studies. His paternal grandfather was physician to the Duke Karl von Württemberg, who founded the Karl's medical school made famous by Schiller. Jaeger's father was one of the world's most respected ophthalmologists and was physician to Prince Metternich, the Iron Chancellor. His mother was the daughter of Georg Joseph Beer, who, under the direction of Empress Maria Theresa, had given modern ophthalmology its academic roots, turning it from a traveling circus into a respected branch of medicine and surgery.

Eduard Jaeger's paternal uncle Carl was the first member of the Jaeger family to pursue ophthalmology. He was one of Beer's first assistants and convinced his brother Friedrich to join him in Vienna. Carl later became a prominent private ophthalmologist in Vienna. Friedrich, who followed in Carl's footsteps and became an assistant to Beer, married Beer's only daughter.

Eduard Jaeger was different from his contemporaries. He was an aristocrat, whereas his colleagues were, by and large, from poor families. His father, Friedrich, was knighted, a title that Eduard was eventually given.

The Jaeger Dynasty

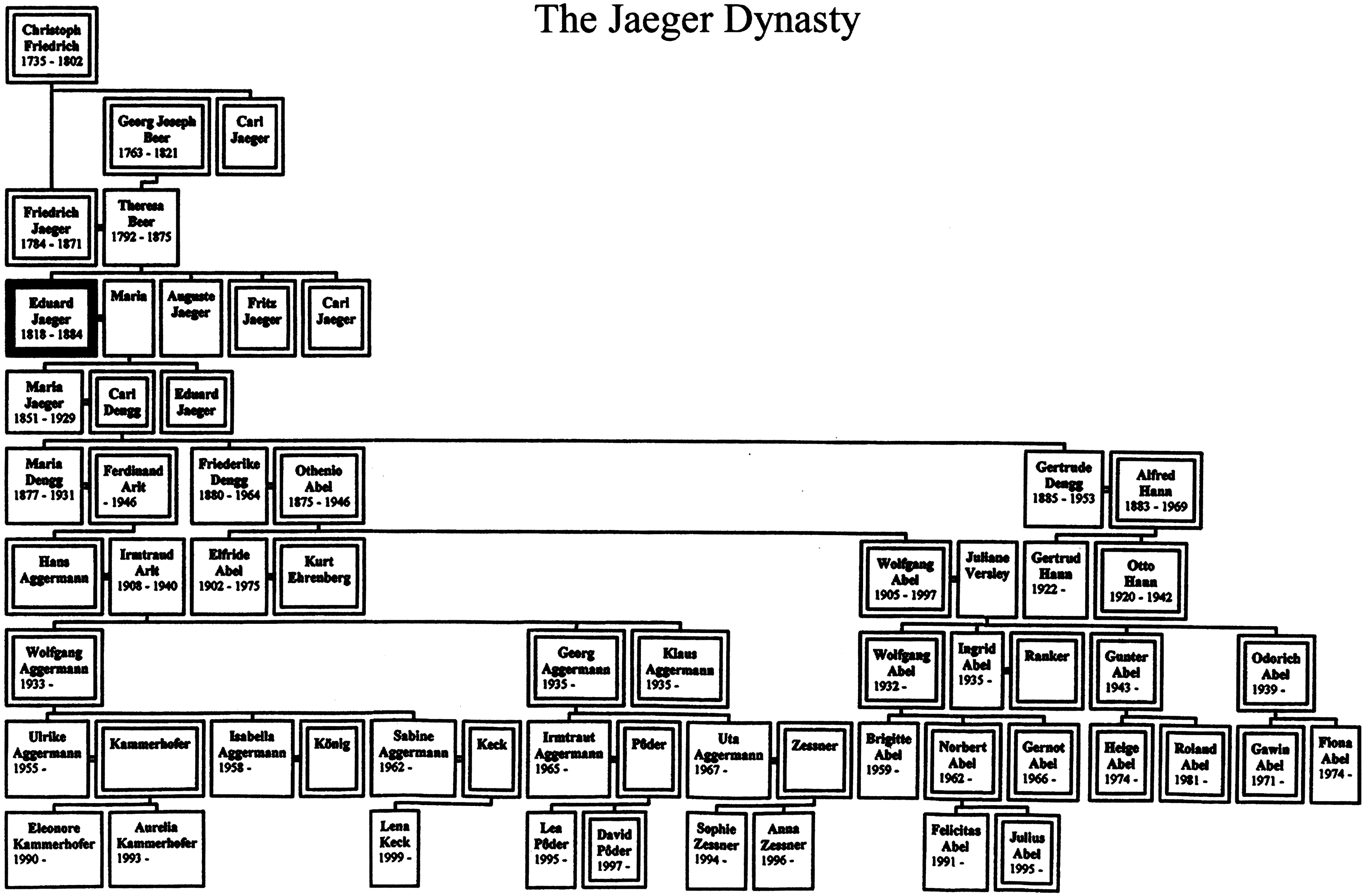


FIGURE 15

Family tree of Eduard Jaeger Ritter von Jaxtthal (1816-1884).

Eduard Jaeger's paternal grandfather, Christoph Friedrich Jaeger, had a disagreement with Duke Karl von Württemberg at one point and moved to Kirchberg on the Jaxt (Jagst) River in the former principality of Hohenlohe (an area northwest of Stuttgart in southern Germany), where Friedrich Jaeger was born. When Friedrich was later ennobled, he took the name Jaxtthal in honor of the place where he was born.[54] Eduard was also subsequently ennobled, and therefore became Eduard Jaeger Ritter von Jaxtthal.

The title Ritter von Jaxtthal literally translates as knight from Jaxtthal, which is the valley through which the Jagst (Jaxt) river flows. The Jagst river is a tributary of the Neckar river, which passes through Heidelberg on its way to the Rhein River near Mannheim.

Heidelberg was another important center in the early evolution of ophthalmology and was the site where the first local ophthalmological society formed, founded by von Graefe, in September 1863. The American Ophthalmological Society formed just 4 months later, in January of 1864, exactly 136 years ago.[55]

Jaeger was in every sense an ophthalmic aristocrat in that he was the last member of the Viennese founding family of ophthalmology where modern ophthalmology has its roots.[54] Eduard Jaeger Ritter von Jaxtthal was born in Vienna on June 25, 1818. He died from complications of pulmonary tuberculosis in Vienna on July 5, 1884, at the age of 66. Eduard Jaeger is buried in Vienna in *Penzinger Friedhof*, a parish cemetery in the 14th district. The cemetery is located at the corner of Ameisgasse and Goldschlagstrasse. He is buried in grave number 360 (Fig 16).

Of the many achievements for which he is remem-

FIGURE 16
Gravestone of Eduard Jaeger Ritter von Jaxtthal. Jaeger is buried in Vienna in Penzinger Friedhof, a parish cemetery in the 14th district. Cemetery is located at corner of Ameisgasse and Goldschlagstrasse. He is buried in grave No. 360.

bered, two stand out: his reading vision Test-Types, which interestingly enough are currently used only in the United States, and his *Atlas of the Ocular Fundus*. All of his monumental achievements required a strong intellect, hard work, persistence, academic curiosity, and attention to minute detail. He had a great sense of family and grieved over the untimely death of his wife, who died at 32 years of age. Until the end, he was a devoted and loving father to his 2 children.

Eduard Jaeger's Early Years

Eduard Jaeger's formative years were spent under the watchful tutelage of his parents in the rarefied air of nobility and medicine. By several accounts, his family home was often filled with a stimulating gathering of individuals, from scholars and artists to aristocrats and state officials. From an early age he learned to be comfortable in this environment; sophisticated behavior became second nature to him. Jaeger's father also thought to include him occasionally when he examined patients or when he performed surgery; his father's clinic was attached to the family home. When Eduard Jaeger was just a young boy, Julius Sichel (Friedich Jaeger's assistant who later became founding Professor of Ophthalmology at the medical faculty in Paris) would carry him through his father's clinic on his back. Even before starting medical school, he was allowed to perform minor eye operations.

Friedrich guided the training of his son with great care. His father hoped that he would carry on the family tradition by becoming a prodigy in ophthalmology and a virtuoso of eye surgery. When Eduard was 22, his father took him to Hanover so that he could assist with an iridectomy on the crown prince. He, therefore, became his father's assistant before undertaking any formal medical studies.

Jaeger's mother was highly intelligent, educated, artistic, and sophisticated. She ensured that Jaeger's early education included proper social behavior and etiquette. This sophisticated behavior, which she instilled, followed Jaeger even into the hospital wards.[54]

Eduard Jaeger's Appearance and Bearing

Jaeger was perceptibly different from his contemporaries. There was something indefinable in his outward appearance, which was truly aristocratic but at times almost quaint. He was tall, thin, and elegant with the restrained, controlled, deliberate movements of a true gentleman. He wore a black coat with long tails and a white bow tie even when making hospital rounds or examining patients in the clinic. His eyes were blue and quick moving, which could appear friendly and smiling or piercing and injurious. He had an unusually high forehead and generous bushy sideburns, which nearly met at his cleanly shaven chin. He maintained his springy gait late into life. He was polite and courteous in speech, behavior, and gestures. He rarely uttered a degrading word, nor spoke of his own misfortune.[54]

Eduard Jaeger's Professional Career

Jaeger completed his medical studies at the University of Vienna under the watchful eyes of his father and was granted the degree of Doctor of Medicine. He subsequently worked as an assistant in his father's clinic for several years before becoming a private lecturer at the University of Vienna in 1854.

In 1855, after the death of the then professor of the eye department, Anton Rosas, Jaeger was insulted when Ferdinand Arlt was chosen to fill the vacant chair rather than himself. Jaeger became bitter and was filled with resentment. He never quite recovered from being passed over for this position. When he finally did receive his full professorship, he made the comment, "Fine but 25 years too late." He became the first chairman of the newly formed Second University Ophthalmology Clinic in Vienna on October 1, 1883, thereby fulfilling his wish of a quarter of a century. This occurred only after the retirement of Professor Arlt. Jaeger unfortunately lived only 9 months and 5 days after achieving his lifelong goal. Julius Hirschberg commented that Jaeger chased after something seemingly unobtainable his entire life and once this goal was achieved, it was ultimately unimportant.[51,56] The deep rift between Jaeger and Arlt was finally mended when two of their grandchildren married. Ernst Fuchs followed Jaeger as the professor in the Second Eye Clinic.

The Second Eye Clinic was established because of the increase in the number of medical students. Many at the university felt that once the numbers in the teaching sessions exceeded 25, the quality of the teaching diminished considerably. Establishing another clinic had been considered 30 years earlier but was decided against because of a lack of funding. At the time of his appointment as full professor to the Second Eye Clinic at the University in Vienna, Jaeger had been Primarius (primary physician and head of the department) at the Vienna Imperial Royal General Hospital for 25 years and associate professor of ophthalmology at the University of Vienna for 26 years.[57]

Jaeger was not only bitter because he was passed over for the professorship at the university, but also because he did not have the success in his private practice that he thought he deserved. Part of the problem was his reserved, withdrawn, and sometimes cold manner; he was much more an academician than a private practitioner. Conversely, his public clinic, which filled with the poor and indigent, was busy. Dr Hann, Jaeger's great-granddaughter, mentioned that Jaeger said, "The poor can not afford to pay and the rich do not want to pay."

Jaeger's lack of success at developing a private ophthalmic practice required that he supplement his income by working as a general practitioner. He was the physician looking after the Archduchess Sophie, the Emperor's mother, during the last days of her life. The general public was often unaware that Jaeger was a famous ophthalmologist. "He smiled recounting the story when as the personal physician of a noble family he was once asked to treat a child with a slight conjunctivitis and was asked whether it would not be advisable to consult an ophthalmologist."[54] Not only did this patient not realize that Jaeger was an ophthalmologist but a rather famous ophthalmologist.

Jaeger lacked both an understanding of the world and the capacity to deal with patients. He also lacked the ego and personality of a surgeon. He became so nervous and excited before operating on a private patient that he could not sleep several nights prior to the operation. However, once operating, his tranquility and assuredness were equal to his boldness and elegance in surgery. He particularly enjoyed ocular plastic surgery and removing eye tumors.

Jaeger was somewhat of a recluse, preferring the solitude of his own company and that of his family to the company of his colleagues. He rarely ventured far from home and almost never attended professional gatherings outside of Vienna. Both socially and scientifically, Jaeger isolated himself from the rest of the ophthalmic community.[57] Jaeger was not a member of the Heidelberg Ophthalmological Society and never attended their meetings. He told Hirschberg in 1871 that he had not left Vienna for years, not even for a single day. Arlt made mention that he felt that Jaeger had done little to keep his medical education up to date after he had completed his formal studies. Jaeger despised the politics of medicine from which he felt victimized. He was seemingly unwilling to participate in what he considered to be the "undignified fight for existence" both academically and professionally. Rather than confront these situations, he would respond by withdrawing into his work. He loved the autonomy of working on independent projects like creating drawings of the ocular fundus, developing new ophthalmic instruments, and working on his Test-Types. He was a tireless perfectionist who enjoyed working late into the night. He obtained great satisfaction from using his lathe to make various mechanical wonders, modifications to Helmholtz's ophthalmoscope, and various surgical eye instruments, including one of the first capsular forceps. He preferred to live withdrawn from the world.

> Eduard Jaeger was an intellectual, an independent thinker, and a scholar. Completely original in this intellectual direction and in his life, he never permitted himself to be swept along with current dominant tendencies of modern ophthalmology but always went his own way. He was always displeased when blind confidence in authority would attempt to suppress the truth. He was a noble creature, an idealist who did not care about materialistic personal gains. He was a true humanitarian who put the welfare of others first. He was modest about his own achievements to a fault and put the achievements of his colleagues ahead of his own. He was respected for his noble and chivalrous character by those who were fortunate enough to be personally close to him.[58]

Once when Jaeger was asked by the Ministry of Health to list his published works, he responded by stating, "Author of more or less unknown works on ophthalmology." This was at a time that his atlas, Test-Types, and other publications were in wide use and distribution.[54]

Jaeger's first book, *Ueber Staar und Staaroperationen*, [On Cataracts and Cataract Operations from my observations and experiences and those of my father], was his professorial dissertation. It contained an unusual collection of material, including data on cataract surgery, accurate drawings of Jaeger's modification of the Helmholtz ophthalmoscope, the first publication of Jaeger's Test-Types, and several fundus drawings. His graduated Test-Types were developed so that he could accurately assess the visual acuity of his patients before and after cataract surgery. Jaeger's collection of Test-Types [*Schrift-Scalen*] was the first test of this type ever published. It contained paragraphs of continuous text (not just single letters, words, or lines of text), increasing in size, which provided an objective method for determining visual acuity. "Ophthalmologists of the civilized world use these vision tests day after day, and day after day they write down Jaeger's name in their notes and in this way extol the memory of the great master."[59]

Jaeger was a dedicated researcher and academician who enjoyed the challenge of determining and teaching the clinical correlates of ophthalmoscopic pathology.[59]

Eduard Jaeger's Legacy

University Lecturer. Jaeger was a poor speaker and therefore a poor lecturer. However, his courses on ophthalmoscopy, ocular pathology, and ocular surgery were unequaled. These sessions were demonstrations and practicals rather than conventional lectures. Doctors from around the world and European royalty came to learn his new skills. The first page of Jaeger's guest book for his clinic and lectures is signed by Albrecht von Graefe and Theodor Leber. In all, more than 1,600 doctors from around the world signed the book. He was free and open with his knowledge. He had a great deal of clinical experience to draw upon for teaching purposes and was therefore highly sought after in this regard. Even though he was not a particularly good lecturer or writer, he was exceptional at teaching the use of the direct ophthalmoscope, demonstrating pathology in living patients, and also by using specimens he collected from patients he had followed in life. He derived a great deal of pleasure from teaching students to use the direct ophthalmoscope to recognize the funduscopic appearance of a range of systemic conditions. These included diabetes mellitus and the choroidal tubercles associated with tuberculosis; and conditions limited to the eye, including macular disease, posterior scleritis, retinal detachments, and the optic nerve changes of glaucoma.[60]

Because of the reputation of ophthalmology in Vienna and the added prestige of the Jaeger dynasty, Jaeger's clinic contained a large cross section of ophthalmic pathology. Although he used the patients in his clinic as teaching aids, he was always kind, considerate, and respectful of them regardless of their station in life.[57] Even at the end of his life, when his health was failing due to pneumonia and pleurisy, he made the extra effort to continue his lecturing. He stated, on more than one occasion, that he enjoyed teaching ophthalmology to beginning as well as advanced students.[54] Jaeger took a leave of absence from his teaching and other responsibilities 11 days prior to his death.

Atlas/Ophthalmoscope. One of Eduard Jaeger's crowning achievements was his artistic documentation of the ocular fundus in both health and disease. This is not surprising when one considers that his father, Friedrich, was the most celebrated ophthalmologist of his time and that his mother, a talented artist, was the daughter of Georg Joseph Beer, who was also an ophthalmologist of stature and an artist in his own right. Eduard Jaeger loved spending hours using the direct ophthalmoscope of Helmholtz to painstakingly record the funduscopic appearance of many disease processes.

The timing for the development of the ophthalmoscope could not have been more perfect for Jaeger. It happened while Jaeger was completing his studies in ophthalmology. This new instrument was rapidly incorporated into clinical practice by young ophthalmologists in training; however, it proved more difficult for the older, established ophthalmologists to learn to use. This fact, coupled with Jaeger's tenacity and artistic ability, catapulted him to the forefront.

> The older generation of ophthalmologists [of Jaeger's day] did not learn this new skill or only became partially proficient with the use of Helmholtz's instrument. Eduard Jaeger's father was among this group. When he saw his son using the direct ophthalmoscope, he would ask with a mixture of astonishment and disbelief, 'Well, do you see anything there?' Thusly was opened a new world and new path for the next generation of young ophthalmologists. Whoever could become proficient with this new instrument could make a name for himself by just examining patients, discovering a world unknown until then, and link his name to the new finding.[54]

At the time Jaeger began using the Helmholtz direct ophthalmoscope, it had already begun to fall out of favor because of its difficulty of use. At the same time, the indirect ophthalmoscope, with its more panoramic image, was becoming increasingly popular. However, as Jaeger stressed, the indirect ophthalmoscope lacked the necessary magnification to provide the detailed image he felt was essential.

Jaeger reintroduced the world to Helmholtz's scope and became the greatest ophthalmoscopist of his day. If it had not been for his tireless promotion of the instrument, his modification of the instrument to make it easier to use, and his outstanding fundus drawings, which demonstrated the advantage of the instrument, Helmholtz's scope (being the predecessor of the modern direct ophthalmoscope) may have been resigned to a small footnote in the developmental history of the ophthalmoscope rather than hold the prominent position it carries today.[54]

Jaeger was one of the first clinicians to use Helmholtz's invention in clinical practice. He altered the scope, making it easier to use. These design changes are documented in Jaeger's book *Ueber Staar und Staaroperationen*. Jaeger was the first individual to describe diabetic retinopathy, optic nerve changes in glaucoma (Jaeger eventually developed glaucoma and cataracts), mylenated nerve fibers, choroidal tubercles, venous pulsations (which Helmholtz could not appreciate), macular disease, posterior scleritis, retinal detachments, embolic central retinal artery occlusion, retinitis pigmentosa, and staphaloma. Jaeger was also the first ophthalmologist to promote the use of the ophthalmoscope for objective determination of refractive errors.[61]

Jaeger revived and promoted direct ophthalmoscopy not only to ophthalmologists but also to general physicians and pediatricians as well. He felt that the ophthalmoscope would one day be more commonly found in the hands of primary care physicians to aid them in diagnosing and caring for their patients. He often stated that the ophthalmoscope interested him more as a physician than as an ophthalmologist and longed for the day that it would take its rightful place along with the stethoscope as a primary diagnostic tool.[51] He hoped to live to see the widespread use of the ophthalmoscope as a general medical instrument.[62]

After Jaeger's wife died, he became even more focused on his work and this instrument. Jaeger continued to document his observations and teach his findings for 33 years, almost up until the day he died.

He continually honed and improved his skills with the instrument. Subsequently, his artistic renditions of the ocular fundi were published in several atlases.

Jaeger's first atlases were published in Vienna in 1855, one of the normal fundus contained 8 plates (reproductions of fundus drawings), and the second of ocular pathology contained 21 plates. In 1869 and 1870, he published two expanded editions, the first contained 29 plates, 128 illustrations, and 236 pages; the second contained 73 plates. Additional volumes appeared through 1894 in German, French, and English. Prior to the publication of his atlases, Jaeger published 8 fundus drawings in *Ueber Staar und Staaroperationen* in 1854. These were pen and ink, black and white, in most editions; however, a few special editions were published that had color drawings. One such example of this special printing is in the collection of the University of Vienna library. Seemingly, only in the painting of his fundus pictures were his painstaking attributes an asset;[63] and I would also add in developing his Test-Types.

Jaeger was passionate about his drawing. He became upset at the work of others because of their lack of accuracy. He disliked schematic representations of the fundus and demanded the most accurate renditions. Jaeger was a perfectionist when it came to his fundus drawings, something that no doubt carried over to his other endeavors. His perseverance was astonishing and devotion admired.[57] For 33 years he created pictures of the ophthalmoscopic appearance of the ocular fundus, nearly until the day he died. Ernst Fuchs commented that 50 years after their introduction, Jaeger's drawings of the ocular fundus had not been equaled[54] Derby, an American doctor who had studied under Eduard Jaeger in Vienna, stated that "Jaeger's pictures of the fundus were still authoritative after 74 years."[60] Jaeger's atlas has recently been republished.[64]

Many of Jaeger's images were republished without his permission, which angered him. However, what really infuriated Jaeger was not so much that this was done, but rather that these images were frequently reproduced so poorly. At times the images would even be mislabeled. This so disturbed Jaeger that he closed the preface to his *Ophtholmoskopischen Hand Atlas* published in Vienna in 1869 with the following admonition:

> Finally I must request those who are inclined or accustomed to copy or reprint the work of others, appropriating their property, in order to obtain illustrations for their own writings without trouble, from lack of material or the ability, or as some publishers, in order to simply make money, or when they, against my expressed wish (as has occurred) use my drawings as original, I request that they will have them placed in hands sufficiently skilled and truthful, in order that my pictures may not be absolutely mutilated and appear but caricatures of nature.[65]

Although Jaeger was critical of his own talent as an artist, he felt that he was able to produce an accurate rendition of the ocular fundus, having devoted hours to each drawing.

> I do not want to interpret things into my pictures, to establish theories or explain things; I merely want to draw. What I have seen is and remains because nature remains. Those who come after me can make out of these pictures whatever they wish; they can offer more accurate explanations should mine be inaccurate. Natural truth remains and cannot be passed off.[66,51]

No matter how diagnosis, prognosis, or treatment may change, these portraits of disease will remain as a classic monument to the industry, patience, and perseverance of Professor Jaeger.[65]

Jaeger had no formal training in art or drawing and often made this purported shortcoming known; however, both his maternal grandfather and his mother were talented artists. In addition, his granddaughter, Gertrude Hann, an artist in her own right, created the relief of Jaeger, which is located in the courtyard at the University of Vienna. Jaeger's bust is located on the north side of the quadrangle next to Ernst Fuchs (Fig 17). The bust of Arlt is at the northwest corner.

Test-Types. "Jaeger created a second monument for himself, by grouping paragraphs of text of increasing font size, the first complete collection of this type for determining visual acuity."[59] Jaeger had for the first time put together print samples from the Imperial Royal Printers that were so numerous in the number of letters, in size, and correctly chosen dimensions that one could determine the smallest differences in visual acuity using them. These samples are designed primarily for testing reading vision. However, Jaeger and Donders used his test for both near and distance vision testing. In fact, Jaeger states that he placed some of his larger types on the side of a building, which were then visible through a window to use for testing distance vision. Fuchs stated, "Today we know that the correct determination of visual acuity is only possible by testing distance vision. But it was not Jaeger's fault to use this principle because the needed preconditions, the theoretical findings of Donders, were still missing at that time."[54] Today we realize that Jaeger was correct in that near and distance visual acuity measurements correlate as long as the correct distances are maintained for each letter size. Jaeger's reading test was a useful and practical tool even though it did not follow strict scientific principles. This is most clearly demonstrated by the fact that "even though several other similar tests based on correct princi-

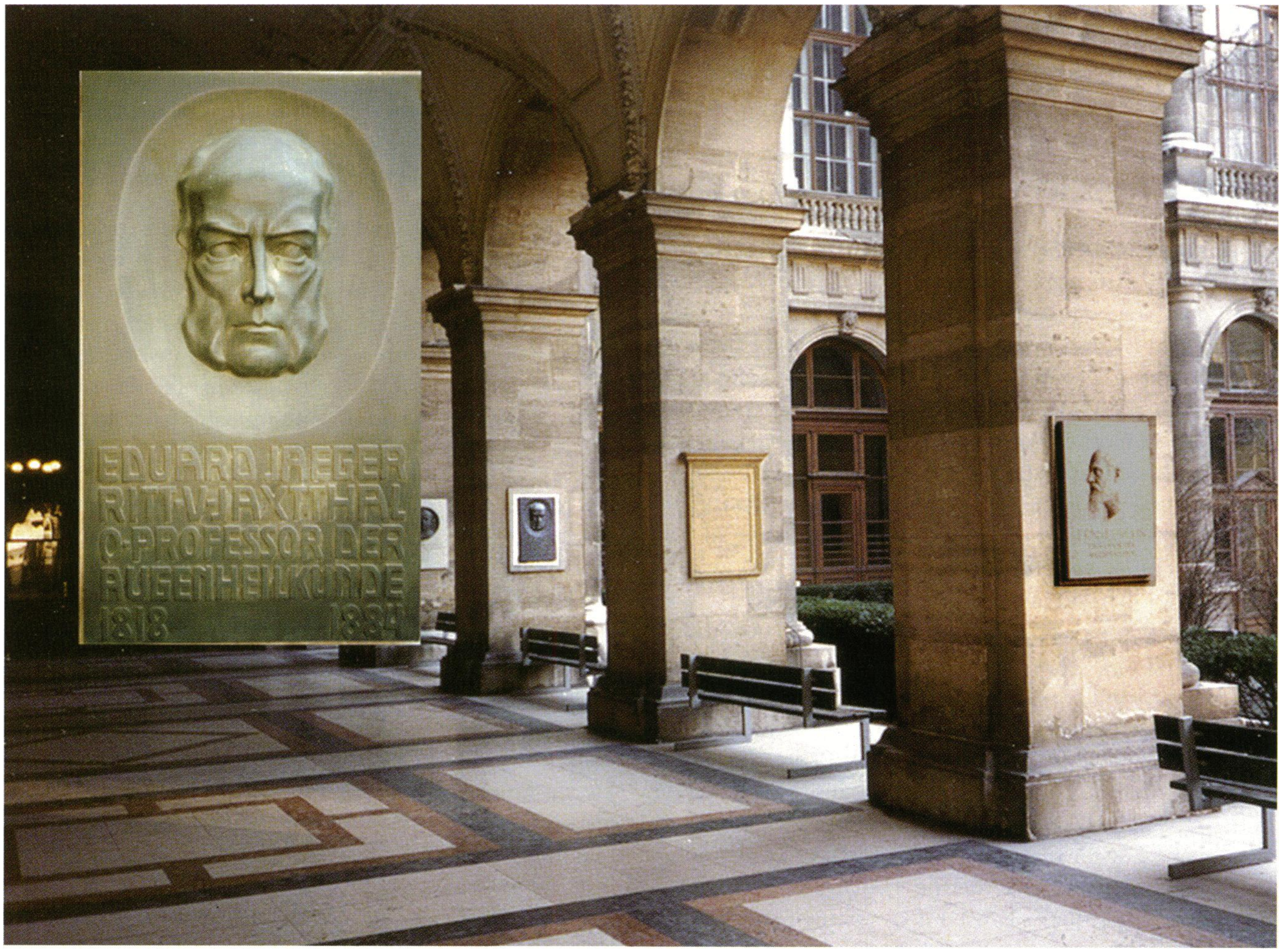


FIGURE 17
Relief of Eduard Jaeger in courtyard of the University of Vienna. Ernst Fuchs's image is on first column (foreground) and Eduard Jaeger's likeness is on third column (background). Inset is enlargement of Jaeger's relief, which was created by Gertrude Hann, Jaeger's granddaughter. Other notable individuals immortalized in this courtyard include Sigmund Freud (1856-1939) and Ignaz Philipp Semmelweiss (1818-1865).

ples have been published, none have come close to achieving the distribution of Jaeger's throughout the entire civilized world."[57]

Jaeger brought his considerable genius to bear on the development of a practical reproducible vision test. Jaeger used the *Staatsdruckerei* in Vienna to reproduce his publications because of the reputation for quality that facility possessed. He made a great financial sacrifice to have his works published. In fact, he contributed 24,000 guilders to defer the cost of printing his atlas. This represented a huge sum, considering his modest income. Jaeger managed to pay off the debt slowly. It is likely that he did the same for his *Schrift-Scalen*.

Jaeger's Test-Types were published in many languages. They were distributed internationally and are still used today. Anyone else would have made a small fortune from the Test-Types and atlases; Jaeger in his noble style dismissed the chance to have any material advantage from them. The Test-Types together with the ophthalmoscopic atlases have surpassed all other works of Jaeger.[54] Jaeger dedicated his first book, *Ueber Staar und Staaroperationen*, along with the first printing of his Test-Types, to his student and close friend, Albrecht von Graefe.

It is surprising that there is relatively little information on Jaeger's struggle to develop his Test-Types and so much information on his atlases and fundus drawings. The university archives referred to by Professor Wyklicky may contain additional information regarding the development of Jaeger's Test-Types.[50] Mr Walter Wieselberg, the archivist at the *Staatsdruckerei* in Vienna, states that all of the materials relating to Jaeger and his Test-Types were destroyed when the buildings were bombed during World War II.

MATERIALS AND METHODS

JAEGER'S TEST-TYPES

All of Jaeger's original eye tests were evaluated and a complete set of photocopies compiled. Original copies of the 1854, 1896, and 1909 editions were also obtained. The majority of these eye tests were evaluated at the library of the University of Vienna; however, several additional eye tests were reviewed in the collection of the Austrian National Library, also in Vienna, and the National Library of Medicine, History of Medicine section, in Bethesda, Maryland.

LINEAR MEASUREMENTS OF JAEGER'S TEST-TYPES

Measurements of the height of all of the Jaeger letters were made using a Microscale (produced by Max Levy Autograph, Inc, 220 W Roberts Ave, Philadelphia, PA 19144; part number MLA0030-001, red scale, 6-inch Microscale, 0.001"/0.025 mm divisions) (Fig 18). Side lighting with a Welch-Allen Finnoff Transilluminator (model 41100, Welch Allyn Medical Products, 4341 State St Rd, Skaneateles Falls, NY 13153) was used to illuminate the scale.

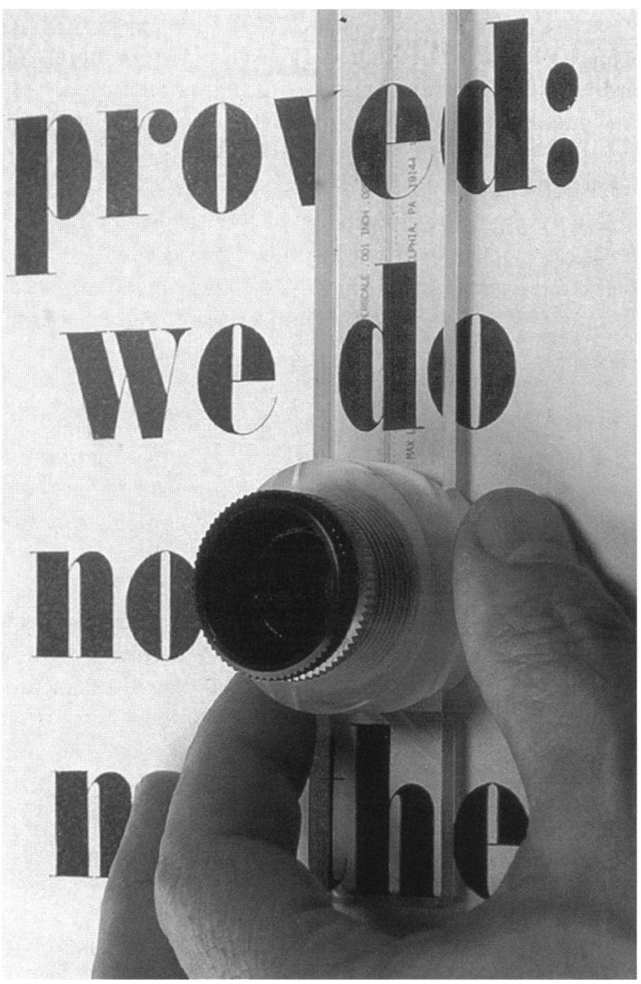


FIGURE 18
Max Levy Microscale with 20X loupe used to measure letter height of Jaeger's Test-Types. Text shown is J20, English Bodoni typeface, standard Viennese edition.

EMPIRICAL MEASUREMENTS OF JAEGER'S TEST-TYPES

Empirical determinations of M units were performed in the following manner. An original copy of Jaeger's *Schrift-Scalen* published in 1909 was obtained from Wilhelm Maudrich KG in Vienna, Austria, for $20, including postage and handling. This particular copy of Jaeger's *Schrift-Scalen* had never before been used because the pages in the booklet were not separated. The pages were therefore cut with a guillotine used to cut reams of paper. The individual pages were then dry-mounted 3 to a page; German, French, and English, side-by-side, on acid-free, one-quarter-inch foam core. The specimens were then placed onto an easel at the end of a long, straight corridor and flooded with light from 2 halogen bulbs, 250-W units (distributed by Leen & Associates, The Designers Edge, 11730 NE 12th St, Bellevue, WA 98005), which were used to supplement one existing 90-W halogen ceiling-mounted floodlight (Master line, Philips Lighting Co, 200 Franklin Square Dr, Somerset, NJ 08875). Light intensity was measured at the surface of the pages of text and was found to be from 80 to 100 foot-candles.

All distance measurements were taken using a Disto memo laser distance-measuring device (Leica Geosystems, Inc, 3155 Medlock Bridge Rd, Norcross, GA 30071) (Fig 19A). This device has an accuracy of less than 3 mm (records to an accuracy of 1 mm) at distances of 30 cm to 100 m. The device was held against the subject's right temple, the front surface of which was aligned with the front surface of the cornea (Fig 19B). The subject was then positioned at a distance at which the type specimen appeared blurred and either walked up to the type until it appeared clear or used a chair with wheels to move gradually toward the type, stopping when the type first appeared clear. Five measurements were taken for each size of type. This process was repeated on 5 occasions over a 1-month period. The data from each session were recorded using the memory registers of the Disto memo. Subsequently, the manual recall function of the device was used to transfer the data to a laboratory note book. Although most of the data were consistent for all of the data-gathering sessions, there was a learning curve, which led to increased consistency of data on the final 2 days that measurements were collected. It was therefore decided to use the data collected from the final 2 days for the purposes of this study.

Jaeger's 1909 Test-Types were compared empirically to the standard ETDRS distance eye chart number 2104 (produced by Precision Vision, 944 First St, La Salle, IL 61301). This was accomplished by placing the ETDRS chart directly above and in the same plane as Jaeger's

FIGURE 19A
Leica Disto, laser-measuring device, which can determine distances from 30 cm to 100 m with an accuracy of 1 mm.

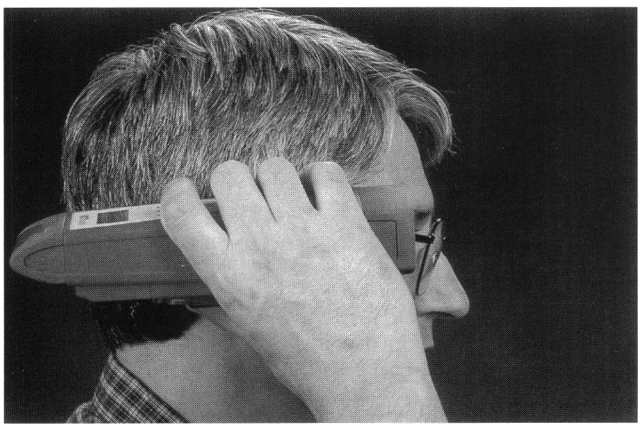


FIGURE 19B
Leica Disto positioned against temple with its front surface aligned with surface of cornea in order to obtain Snellen M unit measurements directly (meter distance at which test object subtends 5' of arc).

mounted Test-Types. This permitted direct comparisons of both charts.

DATA ANALYSIS

All of the data obtained empirically or from linear measurements were manually entered into Microsoft Excel. Graphs and tables were produced directly from the Excel spreadsheet using built-in functions.

RESULTS

JAEGER'S STANDARD TEST-TYPES

Linear Measurements
The 10 primary editions of Jaeger's Test-Types published from 1854 through 1909 in Vienna have been examined and compared directly using a contact sheet transparency. All of the typefaces, font sizes, and text of these original reading vision tests are consistent with few exceptions.

The height of lowercase letters was measured for line letters without ascenders and descenders (i, k, m, n, r, u, v, w, x, z) and round letters (c, e, o). From 11 to 111 letters were measured for each of 24 letter sizes. A sample of the data collection and analysis form using Microsoft Excel is noted in Table II.

Subpopulations of Letters. Line letters were found to be slightly smaller than the round letters, with somewhat more variability in height. However, because the task of reading involves looking at a collection of all of these letters, not a specific subpopulation, it is more logical to use the arithmetic mean of all of these letters to calculate the visual angle rather than any single subpopulation. The entire population of all lowercase letters was utilized for the majority of remainder of the study; however, when a previous investigator specified a subpopulation of lowercase letters, the comparable subpopulation was utilized. Table III contains measurements of the average lowercase letter heights (without ascenders or descenders), J1 through J24; for all of the letters, line letters and round letters. Snellen M unit (which is the meter distance at which a letter of a certain height subtends 5 minutes of arc) equivalents and *n* (number of letters measured) values are also noted in this Table. The data are presented graphically in Fig 20. There is little variation in the height measurements of these 3 groups of letters.

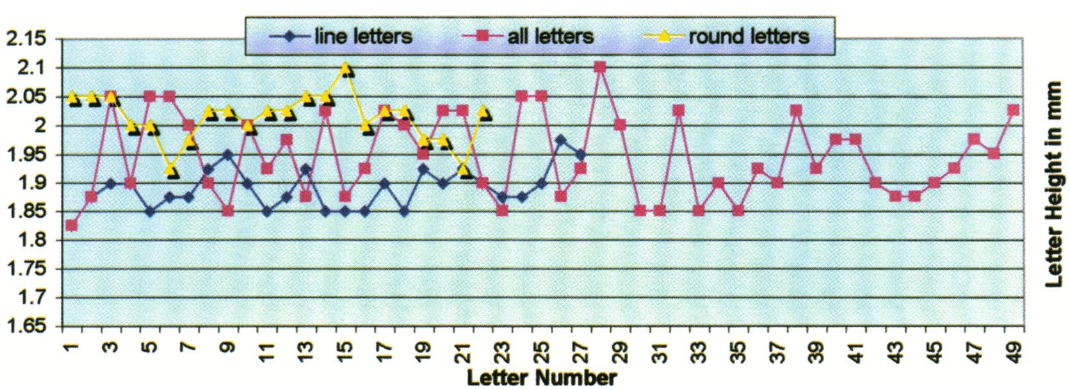
The values for the average of the height of all of the lowercase letters (without ascenders and descenders) are displayed logarithmically in Fig 21, which includes a best-fit curve. The values closely approximate an exponential function.

Current Data Compared With Historical Data
The letter height from Table III, all lowercase letters in the current study, was compared with measurements collected by all previous authors. Table IV contains the values for lowercase letter height measurements (round letters, modern French/English Bodoni font) obtained by Williams[67] (1904) and from the Public Health Report[68] (1931). The measurements are nearly identical, within limits of statistical sampling error. The data are depicted in Fig 22. Table V contains the values for lowercase letter height measurements (line letters without ascenders and descenders, modern French/English Bodoni font) obtained by Pergens[69] (1906) and Birkhäuser[70] (1918). The letter height measurements compare favorably with those contained in the present study. The data are depicted in Fig 23.

Snellen's Data. Snellen measured the letter height of several of the type sizes that make up Jaeger's Test-Types and also determined M-unit equivalents empirically for the same sizes of type. Snellen's data are consistent with current and historical measurements (Table VI, Fig 24)

TABLE II. STANDARD DATA COLLECTION FORM FOR ANALYSIS OF JAEGER'S TEST-TYPES. THIS EXAMPLE INCLUDES LETTER HEIGHT MEASUREMENTS FOR J10 ENGLISH LETTERS FROM JAEGER'S STANDARD TEST-TYPES, VIENNESE EDITION. THE FAR LEFT COLUMN CONTAINS LETTER HEIGHT MEASUREMENTS AS THEY WERE COLLECTED. THE FAR RIGHT COLUMN NOTES HEIGHT OF LETTERS GROUPED BY SUBPOPULATION, EITHER LINE OR ROUND LETTERS. THE MIDSECTION OF THE FORM IS USED FOR DATA ANALYSIS

J	ht(mm)		All Lowercase Letters				Snellen	Fraction			ht(mm)		J
1	1.825	k		ht(mm)	M units	M units rnd	feet	meters	PrintersPts	PP rnd	1.825	k	1
2	1.875	i	Average	1.945918	1.33791	1.3	65	19.5	11.031978	11	1.875	i	2
3	2.05	e	SD	0.07277							1.9	n	3
4	1.9	n	Skew	0.200275							1.9	n	4
5	2.05	e	Median	1.925	1.32393	1.3	65	19.5	10.913386	11	1.85	u	5
6	2.05	c	Mode	1.9	1.30674	1.3	65	19.5	10.771654	11	1.875	m	6
7	2	o	Trend	1.956694	1.34573	1.3	65	19.5	11.093068	11	1.875	r	7
8	1.9	n									1.925	w	8
9	1.85	u			letter angle						1.95	w	9
10	2	c			5x(MAR)	MAR	Rnd	LogMAR	Rnd		1.9	i	10
11	1.925	o	Average	1.945918	16.7238	3.3447609	3	0.524365	0.5		1.85	r	11
12	1.975	e	Median	1.925	16.544	3.3088057	3	0.519671	0.5		1.875	x	12
13	1.875	m	Mode	1.9	16.3292	3.2658349	3	0.513994	0.5		1.925	r	13
14	2.025	e	Trend	1.956694	16.8164	3.3632822	3	0.526763	0.5		1.85	i	14
15	1.875	r									1.85	m	15
16	1.925	w	Linear Lowercase Letters				Snellen	Fraction			1.85	i	16
17	2.025	e		ht(mm)	M units	M units rnd	feet	meters	PrintersPts	PP rnd	1.9	n	17
18	2	e	Average	1.890741	1.29998	1.3	65	19.5	10.71916	11	1.85	m	18
19	1.95	w	SD	0.036787							1.925	n	19
20	2.025	e	Skew	0.39012							1.9	n	20
21	2.025	c	Median	1.9	1.30674	1.3	65	19.5	10.771654	11	1.925	r	21
22	1.9	i	Mode	1.9	1.30674	1.3	65	19.5	10.771654	11	1.9	w	22
23	1.85	r	Trend	1.867725	1.28454	1.3	65	19.5	10.588676	11	1.875	i	23
24	2.05	e									1.875	n	24
25	2.05	e			letter angle						1.9	n	25
26	1.875	x			5x(MAR)	MAR	Rnd	LogMAR	Rnd		1.975	w	26
27	1.925	r	Average	1.890741	16.2496	3.2499197	3	0.511873	0.5		1.95	w	27
28	2.1	e	Median	1.9	16.3292	3.2658349	3	0.513994	0.5		2.05	e	28
29	2	e	Mode	1.9	16.3292	3.2658349	3	0.513994	0.5		2.05	e	29
30	1.85	i	Trend	1.867725	16.0518	3.2103592	3	0.506554	0.5		2.05	c	30
31	1.85	m									2	o	31
32	2.025	e	Round Lowercase Letters				Snellen	Fraction			2	c	32
33	1.85	i		ht(mm)	M units	M units rnd	feet	meters	PrintersPts	PP rnd	1.925	o	33
34	1.9	n	Average	2.013636	1.38447	1.4	70	21	11.415891	11	1.975	e	34
35	1.85	m	SD	0.041352							2.025	e	35
36	1.925	n	Skew	-0.50451							2.025	e	36
37	1.9	n	Median	2.025	1.39271	1.4	70	21	11.480315	11	2	e	37
38	2.025	e	Mode	2.025	1.39271	1.4	70	21	11.480315	11	2.025	e	38
39	1.925	r	Trend	2.026087	1.39346	1.4	70	21	11.486477	11	2.025	c	39
40	1.975	o									2.05	e	40
41	1.975	o			letter angle						2.05	e	41
42	1.9	w			5x(MAR)	MAR	Rnd	LogMAR	Rnd		2.1	e	42
43	1.875	i	Average	2.013636	17.3058	3.4611567	3	0.539221	0.5		2	e	43
44	1.875	n	Median	2.025	17.4034	3.4806889	3	0.541665	0.5		2.025	e	44
45	1.9	n	Mode	2.025	17.4034	3.4806889	3	0.541665	0.5		2.025	e	45
46	1.925	o	Trend	2.026087	17.4128	3.4825572	3	0.541898	0.5		1.975	o	46
47	1.975	w									1.975	o	47
48	1.95	w									1.925	o	48
49	2.025	e									2.025	e	49



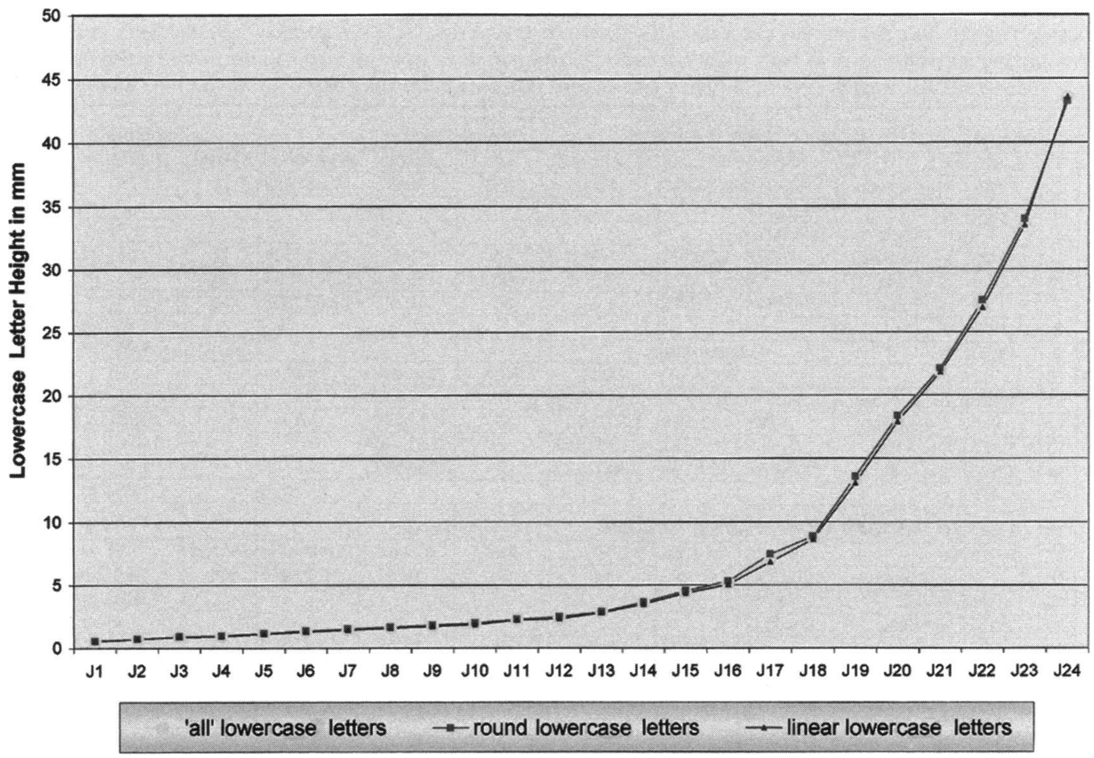


FIGURE 20

Graph of lowercase letter height from Jaeger's Test-Types, standard Viennese edition, demonstrates consistency of current measurements (1999) for all of lowercase letters when compared to round and line letter subpopulations.

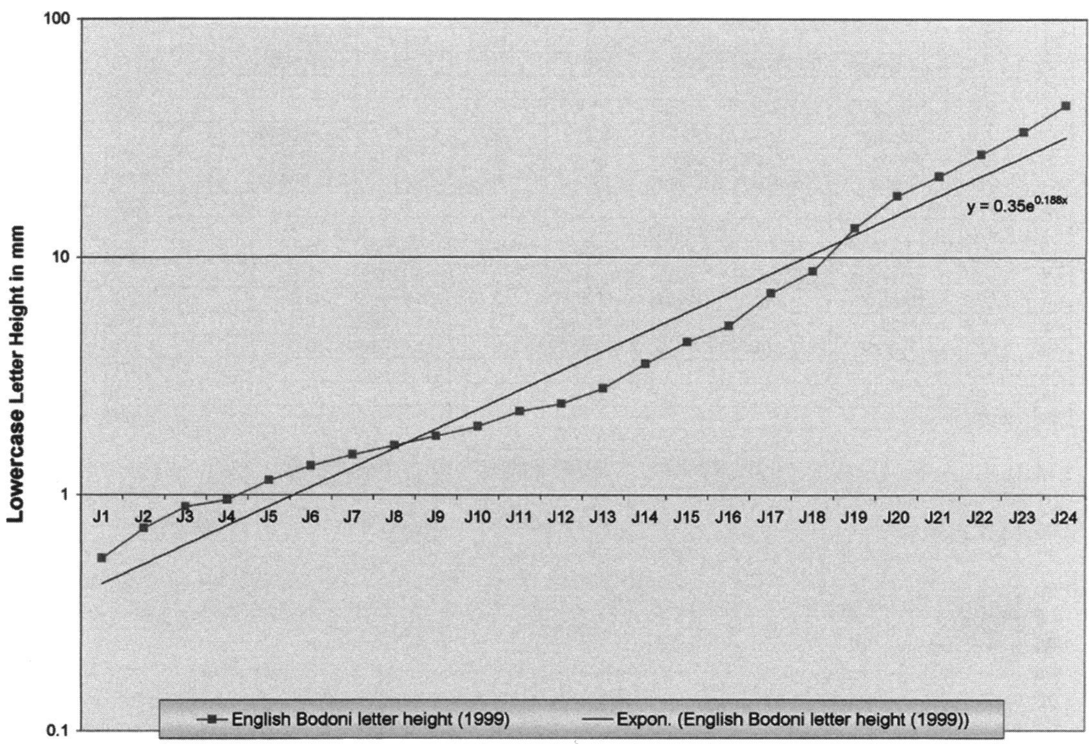


FIGURE 21

Jaeger's Test-Types, standard Viennese edition (logarithmic plot) with trend line, average height of all lowercase English letters (Bodoni) without ascenders or descenders.

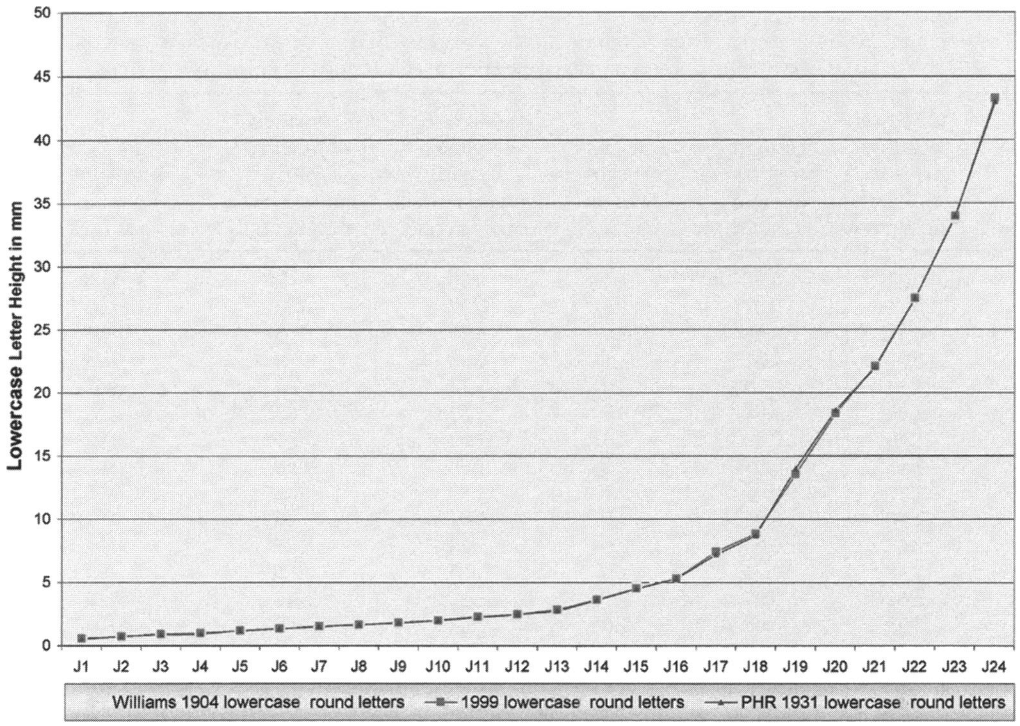


FIGURE 22
Graph demonstrating consistency of letter height measurements performed by Williams (1904) and PHR (1931), lowercase round letters without ascenders or descenders, compared with current (1999) measurements.

TABLE III: AVERAGE MEASURED HEIGHT OF LOWERCASE ENGLISH AND FRENCH LETTERS (BODONI) FROM THE STANDARD VIENNESE EDITION OF JAEGER'S TEST-TYPE WITH CALCULATED M UNITS

	HEIGHT OF ALL LOWERCASE LETTERS IN MM	N	M UNITS	HEIGHT OF LINE LETTERS IN MM	M UNITS	HEIGHT OF ROUND LETTERS IN MM	M UNITS
J1	0.54	105	0.4	0.53	0.4	0.56	0.4
J2	0.72	94	0.5	0.72	0.5	0.72	0.5
J3	0.89	52	0.6	0.87	0.6	0.9	0.6
J4	0.95	41	0.7	0.93	0.6	0.98	0.7
J5	1.15	47	0.8	1.12	0.8	1.18	0.8
J6	1.33	66	0.9	1.3	0.9	1.35	0.9
J7	1.48	59	1	1.44	1	1.52	1
J8	1.62	45	1.1	1.58	1.1	1.66	1.1
J9	1.77	53	1.2	1.73	1.2	1.82	1.3
J10	1.95	49	1.3	1.89	1.3	2.01	1.4
J11	2.25	55	1.5	2.22	1.5	2.29	1.6
J12	2.42	111	1.7	2.35	1.6	2.5	1.7
J13	2.81	93	1.9	2.81	1.9	2.87	2
J14	3.56	86	2.4	3.5	2.4	3.64	2.5
J15	4.41	57	3	4.35	3	4.51	3.1
J16	5.15	55	3.5	5.02	3.5	5.29	3.6
J17	7.06	28	4.9	6.83	4.7	7.43	5.1
J18	8.73	19	6	8.61	5.9	8.84	6.1
J19	13.28	23	9.1	13.06	9	13.56	9.3
J20	18.11	49	12.5	17.93	12.3	18.37	12.6
J21	21.91	39	15.1	21.83	15	22.12	15.2
J22	27.09	41	18.6	26.94	18.5	27.5	18.9
J23	33.65	21	23.1	33.49	23	33.96	23.3
J24	43.5	11	29.9	43.56	29.9	43.25	29.7

N, number of letters measured.

TABLE IV: COMPARISON OF LOWERCASE LETTER HEIGHT FOR THE ENGLISH/FRENCH BODONI TYPEFACE, CURRENT DATA (1999), ROUND LETTERS (C,E, AND O) AS COMPARED WITH MEASUREMENTS PUBLISHED IN THE TRANSACTIONS OF THE AMERICAN OPHTHALMOLOGICAL SOCIETY IN 1904 BY WILLIAMS[67] (TAOS) AND FROM DATA PUBLISHED IN THE PUBLIC HEALTH REPORTS[68] 1931(PHR).

	1999 DATA MEASURED HT.(MM) ROUND LOWER CASE LETTERS	1904 TAOS MEASURED HT.(MM) ROUND LOWER CASE LETTERS	ABSOLUTE DIFFERENCE ROUND LETTERS	PERCENT DIFFERENCE ROUND LETTERS	1999 DATA MEASURED HT.(MM) ROUND LOWER CASE LETTERS	1904 PHS MEASURED HT.(MM) ROUND LOWER CASE LETTERS	ABSOLUTE DIFFERENCE ROUND LETTERS	PERCENT DIFFERENCE ROUND LETTERS
J1	0.56	0.57	0.01	1.8	0.56	0.5	0.06	10.7
J2	0.72	0.71	0.01	1.4	0.72	0.75	0.03	4.2
J3	0.9	0.87	0.03	3.3	0.9	0.85	0.05	5.6
J4	0.98	0.97	0.01	1	0.98	0.9	0.08	8.2
J5	1.18	1.18	0	0	1.18	1.2	0.02	1.7
J6	1.35	1.36	0.01	0.7	1.35	1.35	0	0
J7	1.52	1.48	0.04	2.6	1.52	1.5	0.02	1.3
J8	1.66	1.63	0.03	1.8	1.66	1.65	0.01	0.6
J9	1.82	1.77	0.05	2.7	1.82	1.8	0.02	1.1
J10	2.01	1.96	0.05	2.5	2.01	2	0.01	0.5
J11	2.29	2.23	0.06	2.6	2.29	2.25	0.04	1.7
J12	2.5	2.46	0.04	1.6	2.5	2.5	0	0
J13	2.87	2.82	0.05	1.7	2.87	2.75	0.12	4.2
J14	3.64	3.58	0.06	1.6	3.64	3.6	0.04	1.1
J15	4.51	4.71	0.2	4.4	4.51	4.5	0.01	0.2
J16	5.29	5.46	0.17	3.2	5.29	5.3	0.01	0.2
J17	7.43	7.34	0.09	1.2	7.43	7.2	0.23	3.1
J18	8.84	8.91	0.07	0.8	8.84	8.7	0.14	1.6
J19	13.56	13.58	0.02	0.1	13.56	14	0.44	3.2
J20	18.37	18.39	0.02	0.1	18.37	18.6	0.23	1.3
J21	22.12	22.14	0.02	0.1	22.12	22	0.12	0.5
J22	27.5	27.49	0.01	0	27.5	27.5	0	0
J23	33.96	33.74	0.22	0.6	33.96	34	0.04	0.1
J24	43.25	43.23	0.02	0	43.25	43	0.25	0.6

with one exception. Snellen's quantitative and empirical measurements for J19 and J20 correlate better than expected, and this degree of correlation has not been reproduced by any other investigator. In addition, Snellen's initial empirically derived values, prior to the final correction of his manuscript, are more consistent with the values obtained by previous investigators and achieve better correlation with data contained in the current study (Fig 4). Snellen may have manipulated his empirical data to obtain a better fit, better correlation, with the data he derived from linear letter height measurements.

Schnabel's Data. Schnabel, under the direction and with the assistance of Eduard Jaeger, performed one of the most extensive analyses of Jaeger's *Schrift-Scalen*.[6] In 1876, Schnabel thoroughly evaluated Jaeger's *Schrift-Scalen* by performing numerous measurements of the letter height, intraletter, and intraline distances and also performed extensive evaluations to determine the distance at which a person with normal eyesight could see each of the various type sizes (empirical M units). Schnabel made all of his determinations using the German Fraktur typeface. Table VII contains Schnabel's data, some of which has been recalculated to confirm the validity of the data. Figure 25 demonstrates the consistency of the calculated M units with those values determined empirically for the smaller Jaeger letters; however, the two sets of data diverge as the letters increase in size beyond J15. In addition, Schnabel measured the intraletter and intraline distances and noted that as the letters increase in size, they do not maintain consistency of spacing but rather become relatively crowded. These data are depicted in Fig 26. Schnabel states that the reason for the disparity in the 2 data sets is the decrease in letter and line spacing as the letters increase in size. The current empirical evaluation of the modern Bodoni font Jaeger used for his English and French text demonstrates a similar lack of correspondence for the larger sizes of type.

EMPIRICAL MEASUREMENTS OF JAEGER'S TEST-TYPES

Current Empirical Data

Table VIII contains the values for M units of Jaeger's *Schrift-Scalen* determined empirically by the author and compares them to M units calculated from measurements of letter height. The values are nearly identical from J1 through and including J18. Thereafter, J19 through J24,

TABLE V: COMPARISON OF LOWERCASE LETTER HEIGHT FOR JAEGER'S STANDARD VIENNESE EDITION TEST-TYPES, ENGLISH/FRENCH BODONI TYPEFACE, CURRENT DATA (1999), LINE LETTERS (I, K, M, N, R, U, V, W, X, Z) COMPARED WITH MEASUREMENTS PUBLISHED IN THE ANNALES D'OCULISTIQUE, 1906 BY E. PERGENS[69] AND THOSE COLLECTED BY BIRKHÄUSER[70] IN 1918.

	1999 DATA MEASURED LINE LTRS HT.(MM)	1918 BIRKHÄUSER MEASURED LINE LTRS HT.(MM)	ABSOLUTE DIFFERENCE LINE LETTERS	PERCENT DIFFERENCE LINE LETTERS	1999 DATA MEASURED LINE LTRS HT.(MM)	1906 PERGENS MEASURED LINE LTRS HT.(MM)	ABSOLUTE DIFFERENCE LINE LETTERS	PERCENT DIFFERENCE LINE LETTERS
J1	0.53	0.5	0.03	5.7	0.53	0.5	0.03	5.7
J2	0.72	0.7	0.02	2.8	0.72	0.72	0	0
J3	0.87	0.85	0.02	2.3	0.87	0.84	0.03	3.4
J4	0.93	0.9	0.03	3.2	0.93	0.92	0.01	1.1
J5	1.12	1.1	0.02	1.8	1.12	1.15	0.03	2.7
J6	1.3	1.3	0	0	1.3	1.35	0.05	3.8
J7	1.44	1.4	0.04	2.8	1.44	1.45	0.01	0.7
J8	1.58	1.5	0.08	5.1	1.58	1.55	0.03	1.9
J9	1.73	1.6	0.13	7.5	1.73	1.8	0.07	4
J10	1.89	1.9	0.01	0.5	1.89	1.9	0.01	0.5
J11	2.22	2.1	0.12	5.4	2.22	2.1	0.12	5.4
J12	2.35	2.4	0.05	2.1	2.35	2.3	0.05	2.1
J13	2.81	2.8	0.01	0.4	2.81	2.7	0.11	3.9
J14	3.5	3.5	0	0	3.5	3.35	0.15	4.3
J15	4.35	4.4	0.05	1.1	4.35	4.15	0.2	4.6
J16	5.02	5	0.02	0.4	5.02	5.1	0.08	1.6
J17	6.83	6.7	0.13	1.9	6.83	6.7	0.13	1.9
J18	8.61	8.6	0.01	0.1	8.61	9.5	0.89	10.3
J19	13.06	12.9	0.16	1.2	13.06	13	0.06	0.5
J20	17.93	18	0.07	0.4	17.93	18	0.07	0.4
J21	21.83	21.6	0.23	1.1	21.83	21.5	0.33	1.5
J22	26.94	27.3	0.36	1.3	26.94	27	0.06	0.2
J23	33.49	33.2	0.29	0.9	33.49	33	0.49	1.5
J24	43.56	43.5	0.06	0.1	43.56	43.5	0.06	0.1

the two data sets diverge (ie, the distance at which the letters subtend 5 minutes of arc empirically is less than that predicted from the measurements of letter height). These data are depicted in Fig 27. The explanation for this disparity is that as the letters increase in size, they do not maintain the appropriate letter and line spacing. The intraletter and intraline spacing is less than the letter height or width, making the letters more difficult to recognize. This is a well-recognized effect observed in vision test charts known as the crowding phenomenon.

Jaeger's Test-Types Compared Empirically With an Internal Standard (ETDRS Eye Chart)

Jaeger's Test-Types were further evaluated empirically by applying an internal standard. An ETDRS chart was placed above the mounted pages of Jaeger's tenth edition Test-Types, and subjects were asked to determine the distance at which the Jaeger text became clear. They were then asked to identify which line of the ETDRS chart was equally clear. Photographic representation, in varying degrees of defocus, of the required task, is seen in Fig 28A, B, and C. These data are presented in Table IX and displayed in Fig 29. The M units calculated from the measured letter height, empirically determined and obtained by using the corresponding ETDRS optotype equivalents, are statistically identical up to and including J18; thereafter, the data sets diverge with both the empirical determinations, and ETDRS chart equivalent clarity measured M units becoming more difficult to visualize than one would predict from measured letter height alone. The explanation for this in terms of the Jaeger text is that the intraletter and intraline spacing is not maintained as the letters increase in size and therefore the letters and text become more difficult to recognize. However, the ETDRS chart is designed so that absolute letter and line spacing is maintained throughout the entire chart. Therefore, this phenomenon does not explain the disparity observed in the latter situation. A best-fit exponential function was applied to the data and best approximated the empirically determined and ETDRS data sets, Fig 30.

Current Empirical Data Compared With Historical Empirical Data

Next, the empirical data from the current study were compared with that which was collected by Schnabel (1876) and Becker (1891). One major shortcoming in

TABLE VI: RECALCULATION OF SNELLEN'S DATA[5] (1873) ASSIGNING M UNITS TO JAEGER'S STANDARD VIENNESE EDITION TEST-TYPES, ENGLISH/FRENCH BODONI TYPEFACE, LOWERCASE LINE LETTERS (I, K, M, N, R, U, V, W, X, Z) WITH COMPARATIVE DATA FROM CURRENT MEASUREMENTS (1999). BOTH CALCULATED AND EMPIRICAL DATA ARE INCLUDED.

	SNELLEN'S DATA (1873)							CURRENT DATA (1999)			
	LINE LETTER HEIGHT IN PARIS LINES	LINE LETTER HEIGHT MM	M UNITS RECALCULATED (1999) FROM SNELLEN'S LETTER HEIGHT MEASUREMENTS	DISTANCE AT WHICH LETTERS SUBTEND 5' OF ARC: PARIS FT.	PARIS IN.	EMPIRICAL M UNITS SNELLEN'S CALCULATION	PERCENT DIFFERENCE EMPIRICAL VS CALCULATED BY SNELLEN	LINE LETTER HEIGHT MM	M UNITS CURRENT CALCULATION	EMPIRICAL M UNITS CORRECTED FOR AXIAL LENGTH	PERCENT DIFFERENCE EMPIRICAL SNELLEN VS CURRENT DATA
J1	0.2	0.45	0.309	1	12	0.325	-4.9	0.53	0.4	0.39	-20
J2	0.45	1.02	0.701	2	24	0.65	7.8	0.72	0.5	0.5	23.1
J7	0.6	1.35	0.928	3	36	0.975	-4.8	1.44	1	0.99	-1.5
J11	0.85	1.92	1.32	4	48	1.3	1.5	2.22	1.5	1.36	-4.6
J13	1.15	2.6	1.788	5	60	1.625	10	2.81	1.9	1.72	-5.8
J14	1.5	3.39	2.331	7	84	2.275	2.5	3.5	2.4	2.22	2.4
J18	3.75	8.46	5.817	17	204	5.524	5.3	8.61	5.9	5.92	-7.2
J19	5.3	11.96	8.223	27	324	8.774	-6.3	13.06	9	7.85	10.5
J20	8	18.06	12.417	37	444	12.024	3.3	17.93	12.3	10.56	12.2

The above data is from Snellen's handwritten revision of *Optometrologie die Functionsprüfungen des Auges*,[5] which was published in 1873. Snellen's assignment of M units to Jaeger's test-types are consistent with all historical measurements and current 1999 data. However, it is interesting to note that Snellen's empirical data demonstrates a much better correlation with his calculated data (letter height measurements) for J19 and J20 than that of any other investigator. He does not offer an explanation of how his data was collected and analyzed.

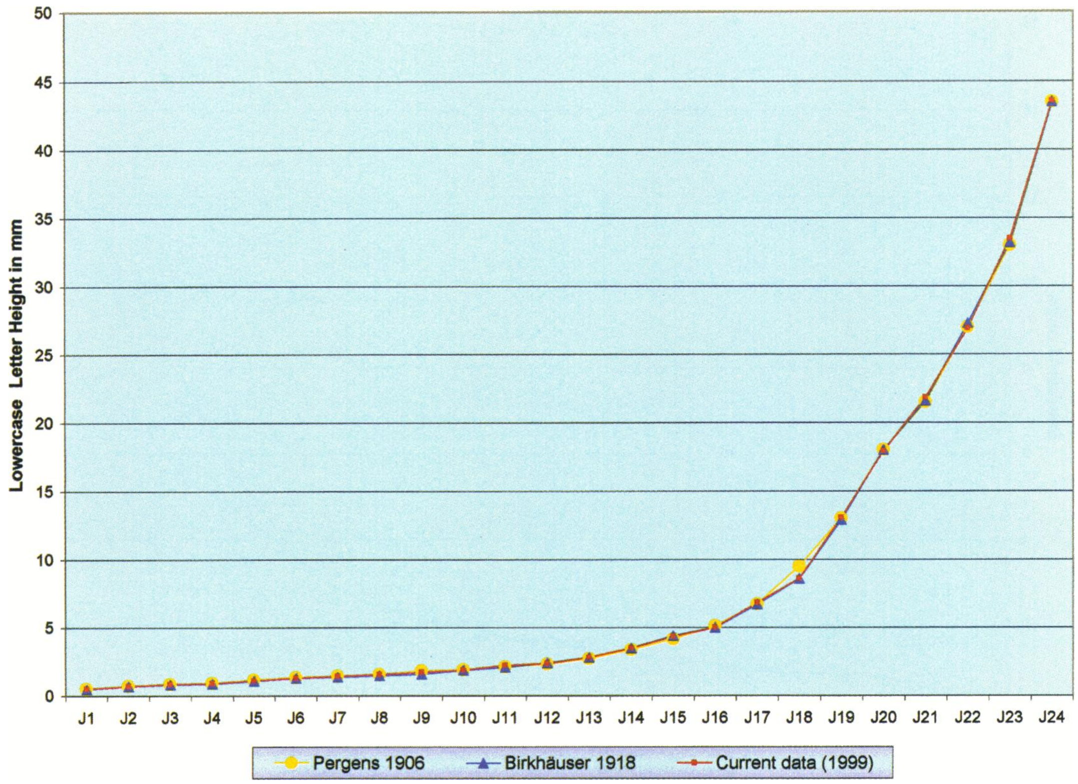


FIGURE 23

Comparison of measurements of lowercase letter height (line letters, ie, i, m, n, r, u, v, w, x) of Jaeger's Test-Types, standard Viennese edition, Bodoni font, obtained by three different investigators. All values are nearly identical.

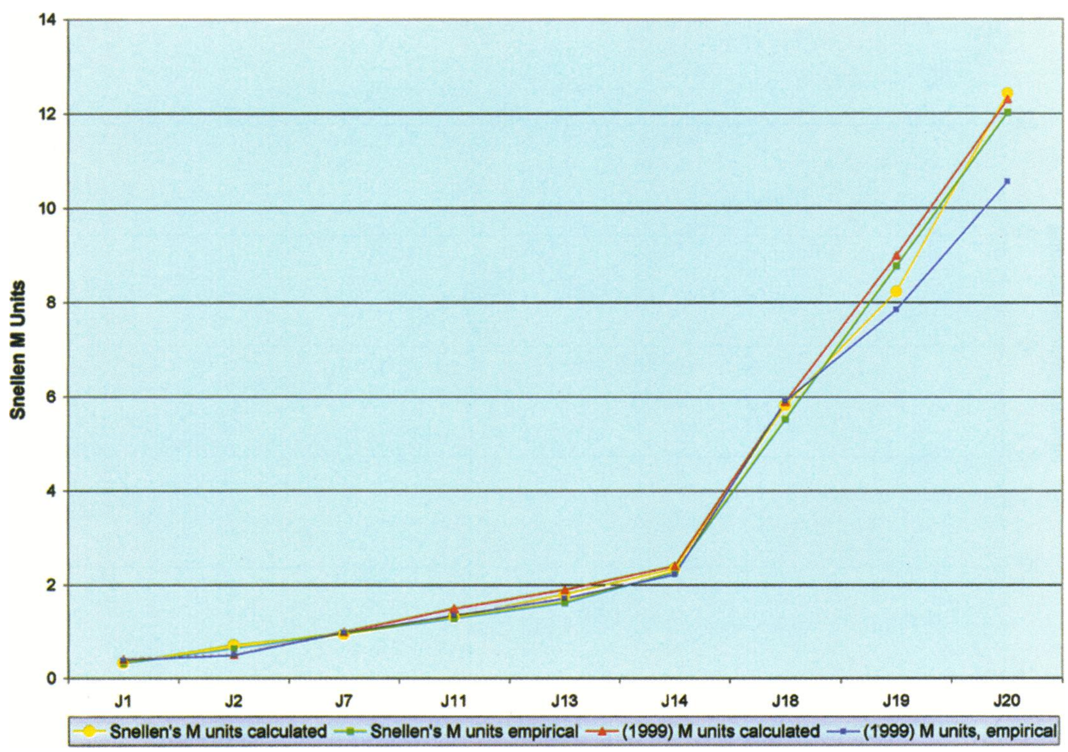


FIGURE 24

Correct Snellen M unit equivalents for Jaeger's Test-Types as determined empirically and from direct linear measurements, by Snellen (1873). Current data (1999) are displayed for comparison.

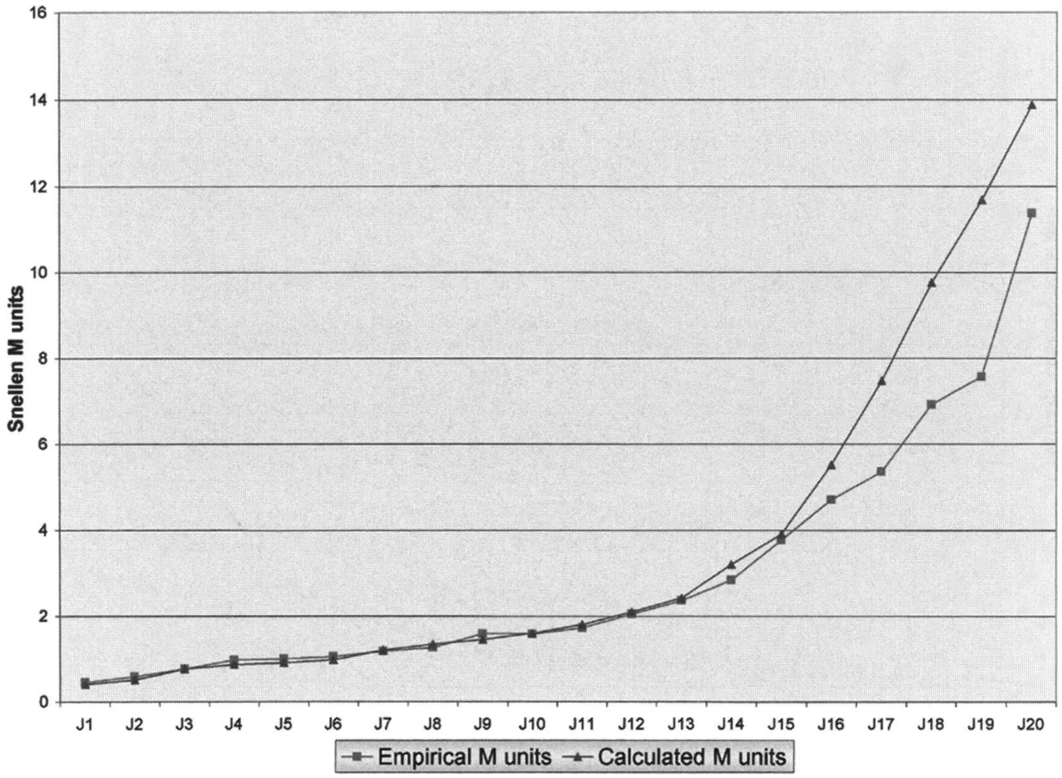


FIGURE 25
Empirically determined versus calculated Snellen M units as measured by Schnabel (1876, Walbaum Fraktur).

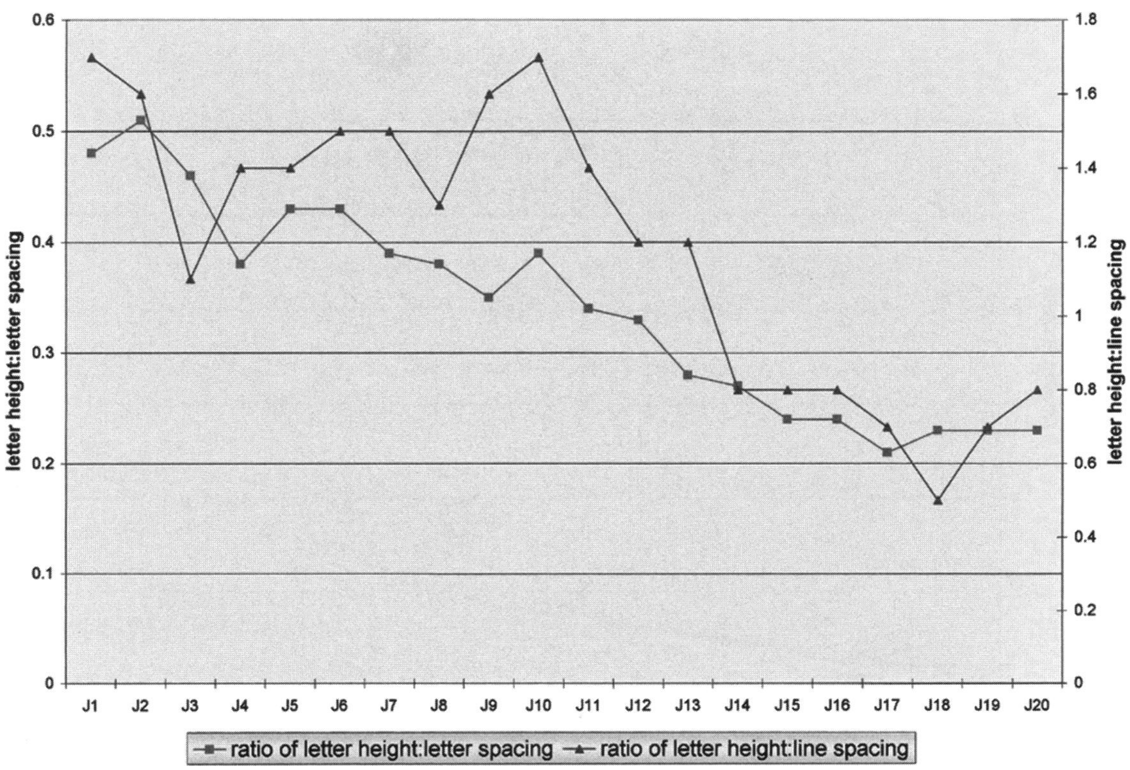


FIGURE 26
Intraletter and intraline spacing of Jaeger's Test-Types, German Walbaum Fraktur, as measured by Schnabel in 1876. Letter and line spacing decrease as letters increase in size, making them more difficult to recognize.

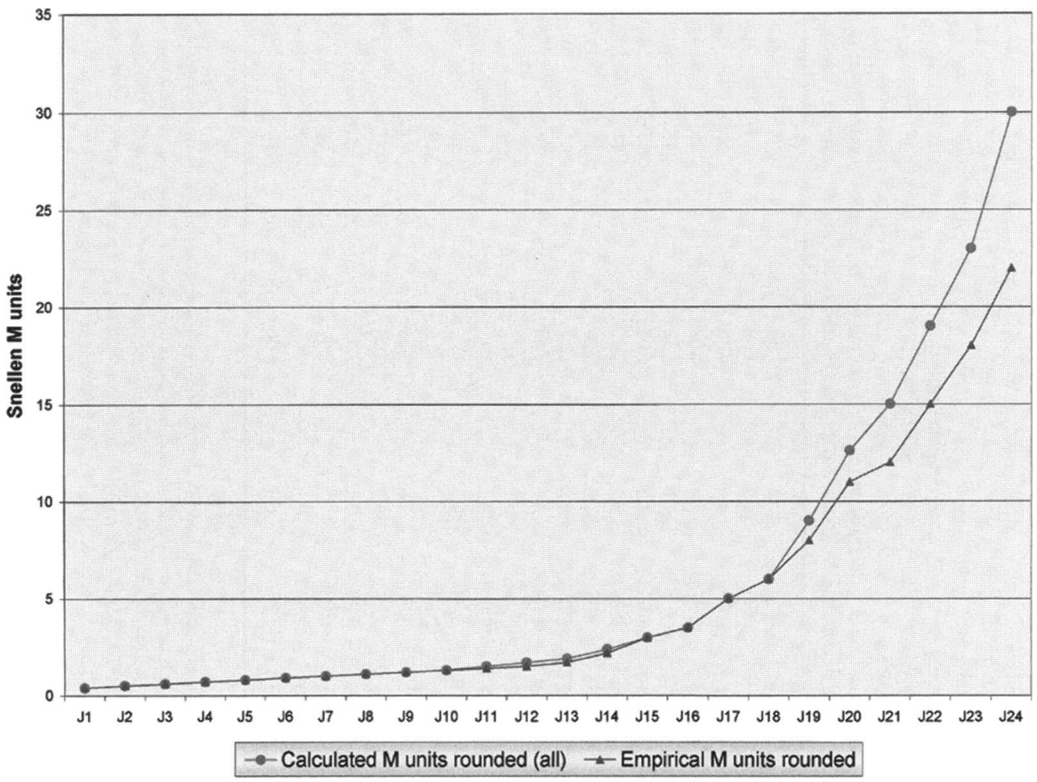


FIGURE 27

Comparison of Snellen M unit measurements for Jaeger's Test-Types (average of all lowercase letters without ascenders and descenders), measured with Microscale versus empirical determinations (subjective) using Leica Disto.

making this comparison is that Schnabel and Becker collected their data using the German Fraktur typeface; English Bodoni was evaluated in the current study. However, it was felt that this might still be a useful comparison because it is likely that Jaeger would have selected letter sizes in the 2 different typefaces that, when compared empirically, would yield the similar results. Table X lists the data for all 3 investigators, including letter height in millimeters and empirical M units. Figure 31 compares the letter height of the German Fraktur to the English Bodoni font. The German letters are slightly larger than the English beginning with J3; however, this difference becomes more marked from J14 to J24. When the letter height measurements for the German Fraktur font obtained by all 3 investigators are compared, all are nearly identical. Figure 32 displays these data (converted to M units) along with Schnabel's empirical data. From J14 through J20, the empirical M units as obtained by Schnabel are significantly smaller than the units obtained by measuring letter height.

Figure 25 (Schnabel) and Fig 33 (Becker) compare empirical to calculated (from letter height measurements) M units for the German Fraktur. They both demonstrate a consistent decrease in the empirically determined M units for the larger letters from J11 to either J20 (Schnabel) or J24 (Becker). That is, the larger letters are more difficult to see than one would predict from measurements of their letter height alone. Figure 34 displays empirical M units obtained by Schnabel, Becker, and the current study. Remembering that the data from Schnabel and Becker are for the Fraktur font, which is larger than the English Bodoni, it is interesting to note that the empirically determined M unit values collected by all 3 investigators are similar for the smaller Jaeger typefaces and demonstrate significant disparity only for the larger letter sizes. The amount of variability in the measurements for the larger Jaeger letters in these 3 data sets is not unexpected, since, as the letters increase in size, the task of determining a precise end point of letter clarity becomes exceedingly difficult. In addition, the crowding phenomenon adds another variable to this already confusing situation.

NONSTANDARD JAEGER'S TEST-TYPES

Linear Measurements

Letter height measurements for the standard Viennese edition of Jaeger's Test-Types, the English pocket edition of Jaeger's Test-Types[46] (also published in Vienna), and the

TABLE VII: MEASUREMENTS OF LETTER HEIGHT AND SPACING FOR JAEGER'S STANDARD TEST-TYPES AS COMPILED BY J. SCHNABEL IN 1876 WITH THE ASSISTANCE OF EDUARD JAEGER. EXTENSIVE LINEAR AND EMPIRICAL MEASUREMENTS HAVE BEEN COMPILED. THE DATA HAS BEEN REASSESSED WHERE APPROPRIATE.

	LETTER HEIGHT		M UNITS	DISTANCE BETWEEN LINES		RATIO OF LETTER SPACING TO LETTER HEIGHT	DISTANCE BETWEEN LINES		RATIO OF LINE SPACING TO LETTER HEIGHT	DISTANCE AT WHICH A NORMAL EYE ("WITH S24/20° LAT.") CAN READ ALL ALL THE WORDS IN THE SAMPLE			CORRESPONDING ANGLE OF VISION		CALCULATED DISTANCE AT WHICH THE LETTERS SHOULD SUBTEND 5' OF ARC SNABEL'S CALCULATIONS		
	PARIS LINES	MM	CURRENT CALCULATION	PARIS LINES	MM		PARIS LINES	MM		PARIS FEET	PARIS INCHES	METERS	SCHNABEL'S CALCULATION	CURRENT CALCULATION	PARIS FEET	PARIS INCHES	M UNITS METERS
J1	0.27	0.61	0.42	0.13	0.29	0.48	0.47	1.06	1.7		16.5	0.45	4.65	4.66		15.3	0.41
J2	0.33	0.74	0.51	0.17	0.38	0.51	0.51	1.15	1.6		21.3	0.58	4.5	4.39		19	0.51
J3	0.48	1.08	0.74	0.22	0.5	0.46	0.51	1.15	1.1		28.1	0.76	4.9	4.89		27.9	0.76
J4	0.55	1.24	0.85	0.21	0.47	0.38	0.79	1.78	1.4		35.9	0.97	4.4	4.39		31.9	0.86
J5	0.57	1.29	0.89	0.25	0.56	0.43	0.81	1.83	1.4		36.9	1	4.6	4.43		33.7	0.91
J6	0.63	1.42	0.98	0.27	0.61	0.43	0.97	2.19	1.5		38.8	1.05	4.7	4.65		35.9	0.97
J7	0.77	1.74	1.2	0.3	0.68	0.39	1.13	2.55	1.5		43.6	1.18	5.1	5.07		44.3	1.2
J8	0.85	1.92	1.32	0.32	0.72	0.38	1.08	2.44	1.3		46.6	1.26	5.25	5.24		49.5	1.34
J9	0.93	2.1	1.44	0.33	0.74	0.35	1.46	3.3	1.6		58.2	1.58	4.6	4.57		53.4	1.45
J10	1.03	2.32	1.6	0.4	0.9	0.39	1.73	3.9	1.7		58.2	1.58	5.1	5.05		59.2	1.6
J11	1.16	2.62	1.8	0.39	0.88	0.34	1.62	3.66	1.4		64	1.73	5.2	5.21		66.5	1.8
J12	1.35	3.05	2.1	0.45	1.02	0.33	1.68	3.79	1.2		75.7	2.05	5.1	5.11		77.6	2.1
J13	1.55	3.5	2.41	0.44	0.99	0.28	1.88	4.24	1.2		87.3	2.36	5.1	5.1		89.2	2.42
J14	2.05	4.63	3.18	0.55	1.24	0.27	1.72	3.88	0.8		104.8	2.84	5.7	5.6		118.3	3.2
J15	2.7	6.09	4.19	0.65	1.47	0.24	2.27	5.12	0.8	11.6	139.2	3.77	5.6	5.55	12	144	3.9
J16	3.6	8.13	5.59	0.87	1.96	0.24	2.89	6.52	0.8	14.5	174	4.71	5.7	5.93	17	204	5.52
J17	4.87	10.99	7.56	1.04	2.35	0.21	3.34	7.54	0.7	16.5	198	5.36	7.1	7.05	23	276	7.47
J18	6.25	14.11	9.7	1.45	3.27	0.23	3.36	7.58	0.5	21.3	255.6	6.92	7	7.01	30	360	9.75
J19	7.5	16.93	11.64	1.74	3.93	0.23	5.04	11.38	0.7	23.3	279.6	7.57	8.9	7.69	35.9	430.8	11.67
J20	8.89	20.06	13.79	2.08	4.69	0.23	6.73	15.19	0.8	35	420	11.37	6.1	6.06	42.7	512.4	13.88

°This is likely a typographical error. It should read 20/20.

Schnabel was a student of Eduard Jaeger. He, with Jaeger's assistance and blessing, worked with Jaeger's Schrift-Scalen to collect the data Snellen and others had requested, ie, M unit equivalents of Jaeger's Test-Types. Unfortunately, he limited his measurements to the German Fraktur typeface. However, two important pieces of information are supported by the above data. First of all, the empirical and actual calculations of the visual angles for Jaeger's test-types are nearly identical, up to and including J15; thereafter they diverge (Fig 25). Secondly, the reason for this divergence is that the spacing between the larger letters progressively narrows, relative to their width, as the letters increase in size. In addition, the spacing between the lines progressively narrows. The letters simply become crowded which makes them more difficult to see (Fig 26). J. Schnabel. *"Ueber die Jäger'schen Schriftskalen."* XIV. Notiz über die Jäger'schen Schriftskalen. *Archiv für Augen- und Ohrenheilkunde*, volume 5, part 1, 1876, p 210-212 for Fraktur.

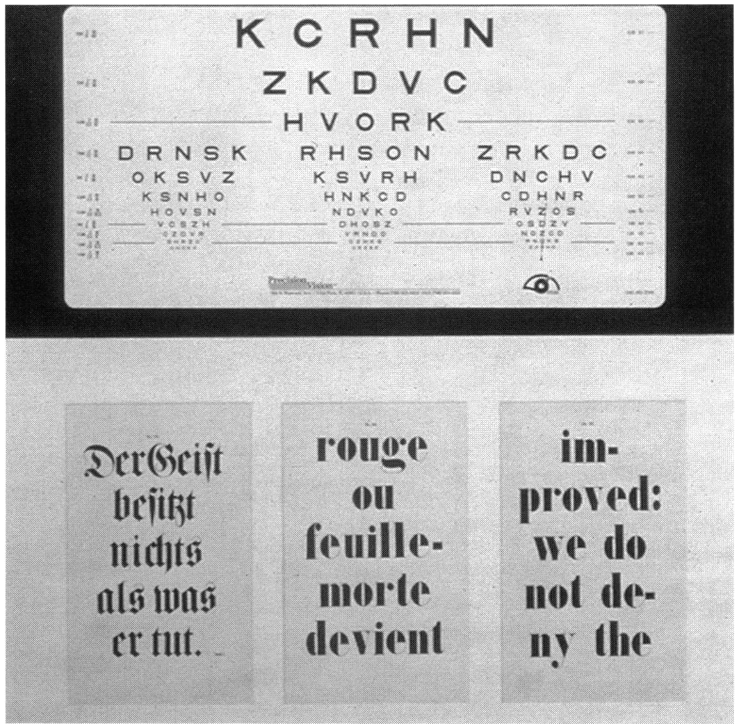


FIGURE 28A

Comparison of a standard ETDRS distance eye chart with Jaeger's Test-Types (J20), standard Viennese edition, Walbaum Fraktur (German) typeface and Bodoni (French/English) typeface. Both Jaeger Test-Types and ETDRS charts appear relatively clear. Subject's task is to slowly approach eye charts and stop when Jaeger type approach this level of clarity. At that point, subject is asked to determine which line of ETDRS chart is equally clear (ie, corresponds to Jaeger type being assessed). This method provides an internal standard to which Jaeger's Test-Types can be compared.

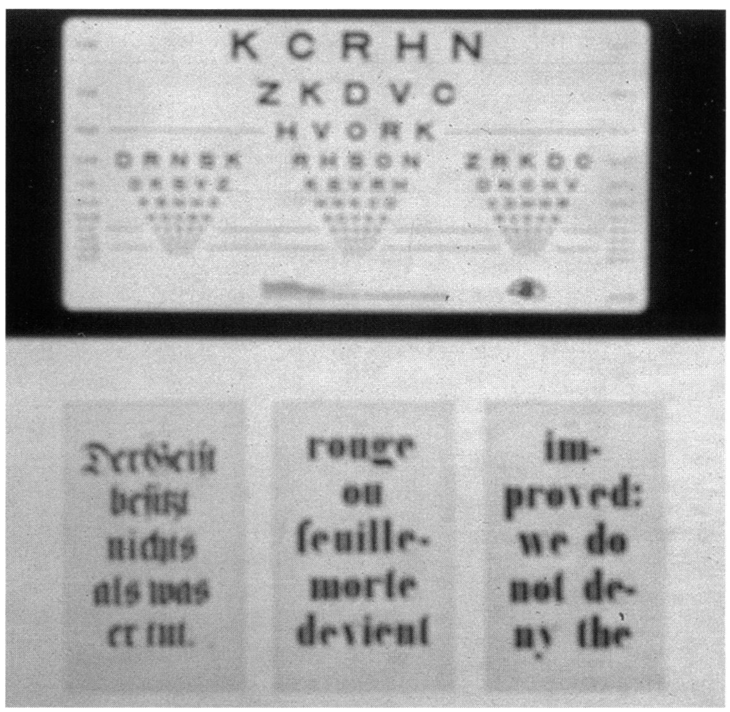


FIGURE 28B

Comparison of a standard ETDRS distance eye chart with Jaeger's Test-Types (J20), standard Viennese edition, Walbaum Fraktur (German) typeface and Bodoni (French/English) typeface. Both Jaeger Test-Types and ETDRS charts appear relatively blurred. Subject's task is to slowly approach eye charts and stop when Jaeger test becomes clear; at that point, subject is asked to determine which line of ETDRS chart is equally clear (ie, corresponds to Jaeger type being assessed). This method provides an internal standard to which Jaeger's Test-Types can be compared.

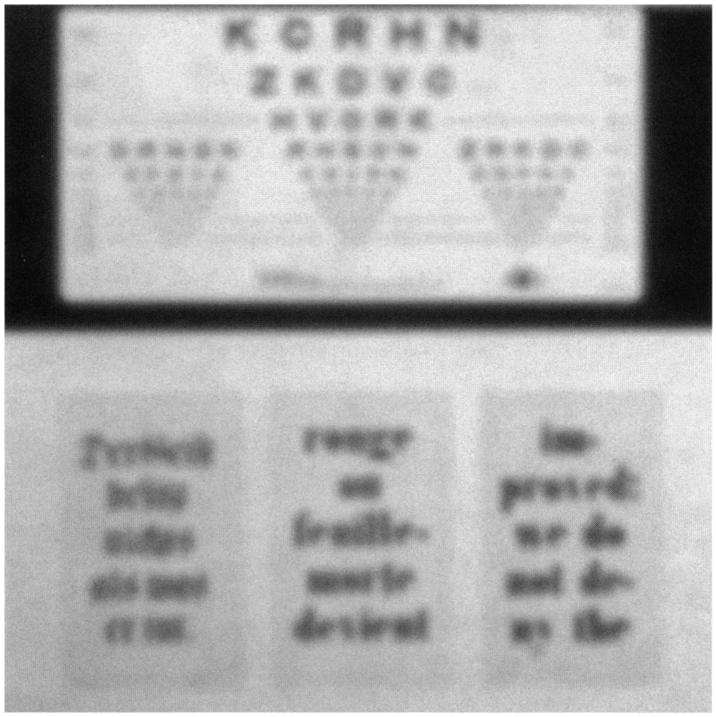


FIGURE 28C

Comparison of a standard ETDRS distance eye chart with Jaeger's Test-Types (J20), standard Viennese edition, Walbaum Fraktur (German) typeface and Bodoni (French/English) typeface. Both Jaeger Test-Types and ETDRS charts appear relatively blurred. Subject's task is to slowly approach eye charts and stop when Jaeger test becomes clear; at that point, subject is asked to determine which line of ETDRS chart is equally clear (ie, corresponds to Jaeger type being assessed). This method provides an internal standard to which Jaeger's Test-Types can be compared.

TABLE VIII: SNELLEN M UNIT EQUIVALENTS FOR JAEGER'S STANDARD EDITION TEST-TYPES, AS CALCULATED FROM LINEAR MEASUREMENTS OF THE LOWERCASE LETTER HEIGHTS COMPARED WITH EMPIRICALLY DETERMINED M UNITS USING THE LEICA LASER DISTANCE MEASURING DEVICE (DISTO).

	HEIGHT OF ALL LOWERCASE LETTERS IN MM	M UNITS	CALCULATED M UNITS FOR JAEGER'S TEST-TYPE ROUNDED	EMPIRICAL M UNITS FOR JAEGER'S TEST-TYPE ROUNDED
J1	0.54	0.4	0.4	0.4
J2	0.72	0.5	0.5	0.5
J3	0.89	0.6	0.6	0.6
J4	0.95	0.7	0.7	0.7
J5	1.15	0.8	0.8	0.8
J6	1.33	0.9	0.9	0.9
J7	1.48	1	1	1
J8	1.62	1.1	1.1	1.1
J9	1.77	1.2	1.2	1.2
J10	1.95	1.3	1.3	1.3
J11	2.25	1.5	1.5	1.4
J12	2.42	1.7	1.7	1.5
J13	2.81	1.9	1.9	1.7
J14	3.56	2.4	2.4	2.2
J15	4.41	3	3	3
J16	5.15	3.5	3.5	3.5
J17	7.06	4.9	5	5
J18	8.73	6	6	6
J19	13.28	9.1	9	8
J20	18.11	12.5	12.5	11
J21	21.91	15.1	15	12
J22	27.09	18.6	19	15
J23	33.65	23.1	23	18
J24	43.5	29.9	30	22

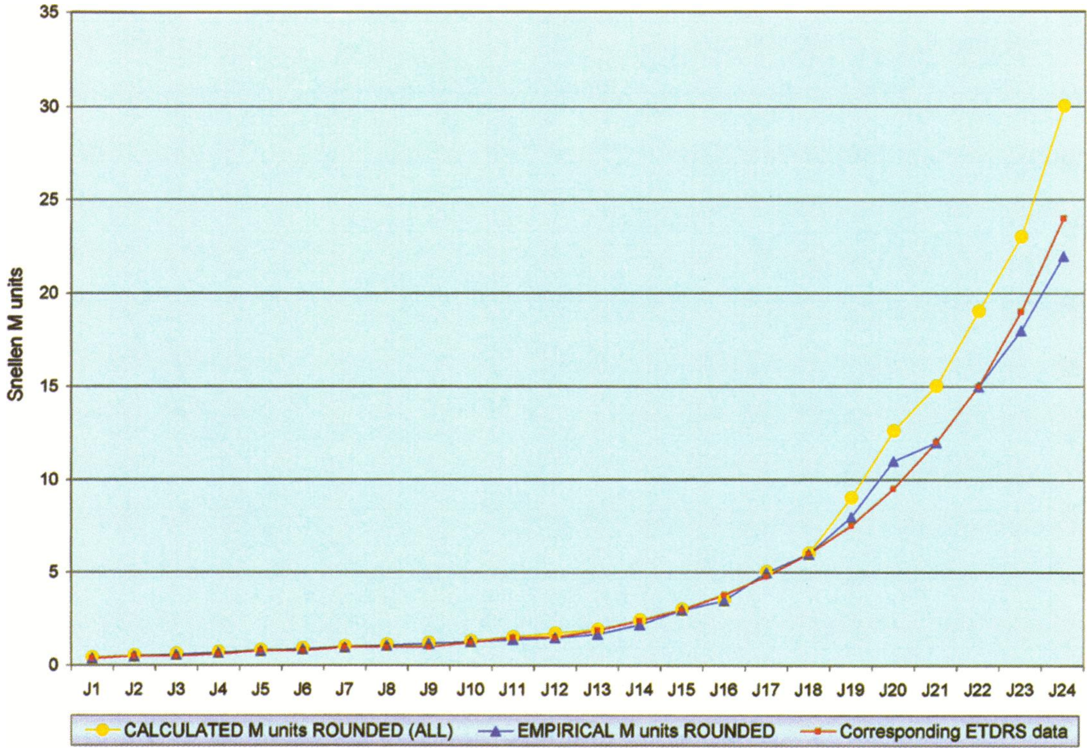


FIGURE 29
Comparison of Snellen M units for Jaeger's Test-Types as measured with Microscale (linear) versus empirical determinations using Leica Disto (subjective). Final comparison is to an internal, ETDRS chart, standard.

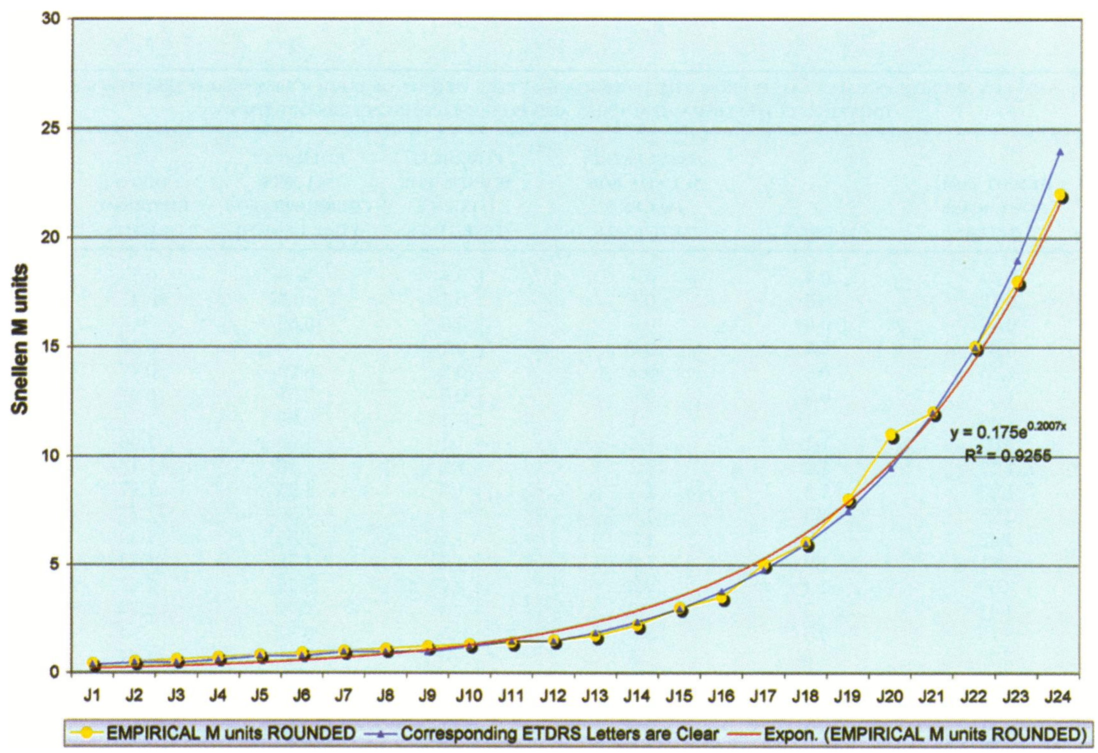


FIGURE 30
Corresponding Snellen M units for Jaeger's Test-Types determined empirically (subjectively) using Leica Disto compared with coresonding ETDRS letters and best fit exponential curve.

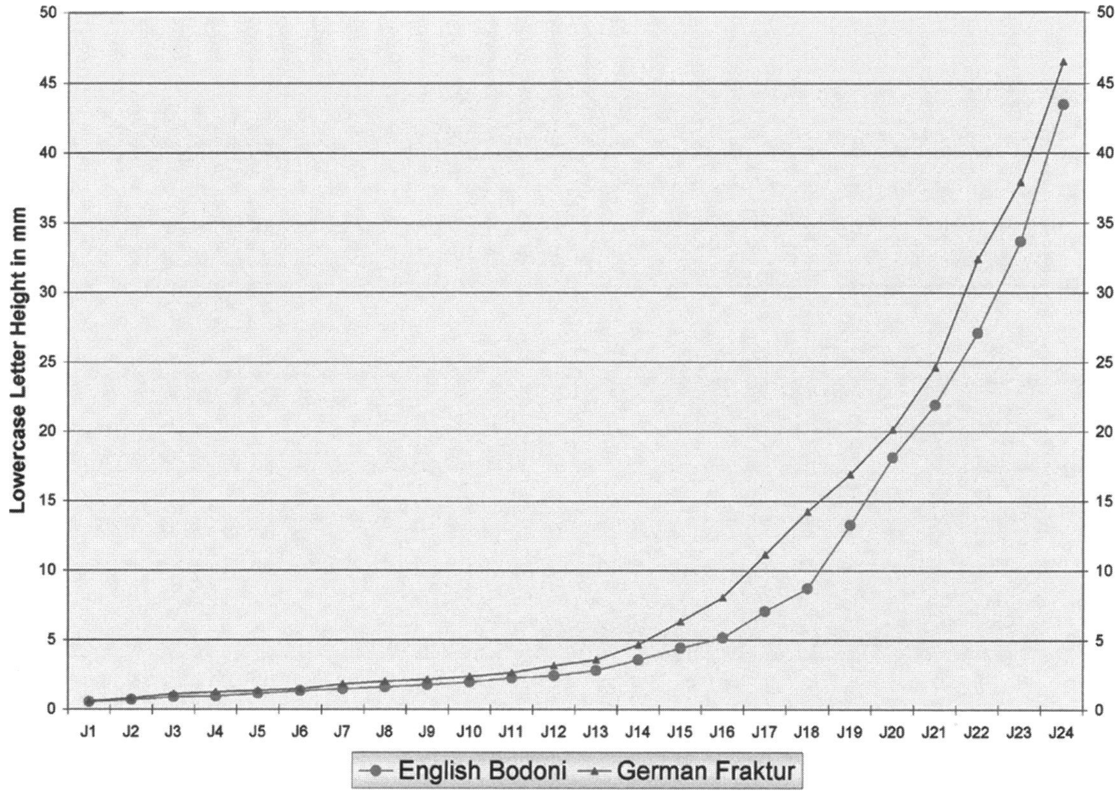


FIGURE 31

Jaeger's Test-Types, standard Viennese edition, German Walbaum Fraktur versus English Bodoni (average height of all lowercase letters without ascenders or descenders).

TABLE IX: SNELLEN M UNITS AS CALCULATED FROM THE LOWERCASE LETTER HEIGHT OF JAEGER'S STANDARD TEST-TYPES COMPARED WITH EMPIRICALLY DETERMINED M UNITS AND CORRESPONDING ETDRS OPTOTYPES.

	HEIGHT (MM) LOWERCASE LETTERS	M UNITS	CALCULATED M UNITS FOR JAEGER'S TEST-TYPES	EMPIRICAL M UNITS FOR JAEGER'S TEST-TYPES	EMPIRICAL M UNITS CORRECTED FOR AXIAL LENGTH	DISTO EMPIRICAL M UNITS	CORRESPONDING ETDRS OPTOTYPES CLEAR
J1	0.54	0.4	0.4	0.4	0.39	0.37	0.4
J2	0.72	0.5	0.5	0.5	0.5	0.47	0.5
J3	0.89	0.6	0.6	0.6	0.62	0.6	0.5
J4	0.95	0.7	0.7	0.7	0.68	0.66	0.63
J5	1.15	0.8	0.8	0.8	0.79	0.77	0.8
J6	1.33	0.9	0.9	0.9	0.91	0.91	0.8
J7	1.48	1	1	1	0.99	1	1
J8	1.62	1.1	1.1	1.1	1.06	1.06	1
J9	1.77	1.2	1.2	1.2	1.16	1.13	1
J10	1.95	1.3	1.3	1.3	1.25	1.27	1.25
J11	2.25	1.5	1.5	1.4	1.36	1.37	1.5
J12	2.42	1.7	1.7	1.5	1.53	1.52	1.5
J13	2.81	1.9	1.9	1.7	1.72	1.73	1.9
J14	3.56	2.4	2.4	2.2	2.22	2.27	2.4
J15	4.41	3	3	3	2.72	2.73	3
J16	5.15	3.5	3.5	3.5	3.37	3.4	3.8
J17	7.06	4.9	5	5	4.91	4.84	4.8
J18	8.73	6	6	6	5.92	5.74	6
J19	13.28	9.1	9	8	7.85	7.54	7.5
J20	18.11	12.5	12.5	11	10.56	9.99	9.5
J21	21.91	15.1	15	12	12.39	11.8	12
J22	27.09	18.6	19	15	14.51	13.9	15
J23	33.65	23.1	23	18	17.63	18.46	19
J24	43.5	29.9	30	22	22.09	21.84	24

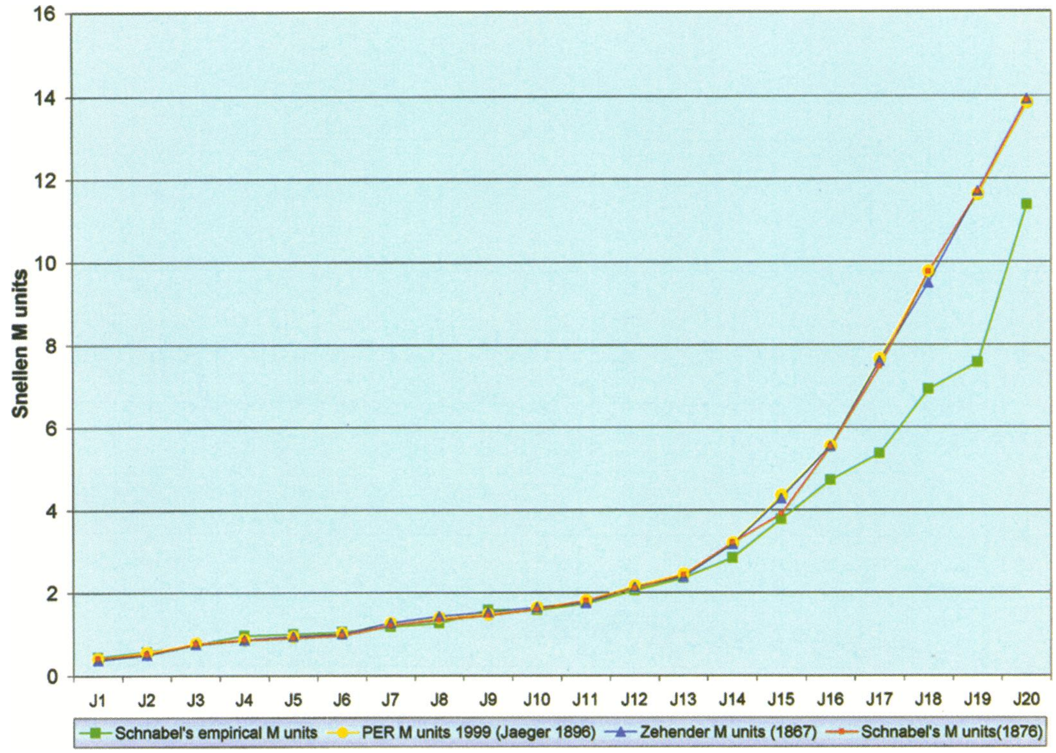


FIGURE 32

Comparison of measurements of lowercase letter height, Walbaum Fractur, measured by Zehender (1867) and Schnabel (1876) compared with current data (1999). Schnabel's empirical data are included.

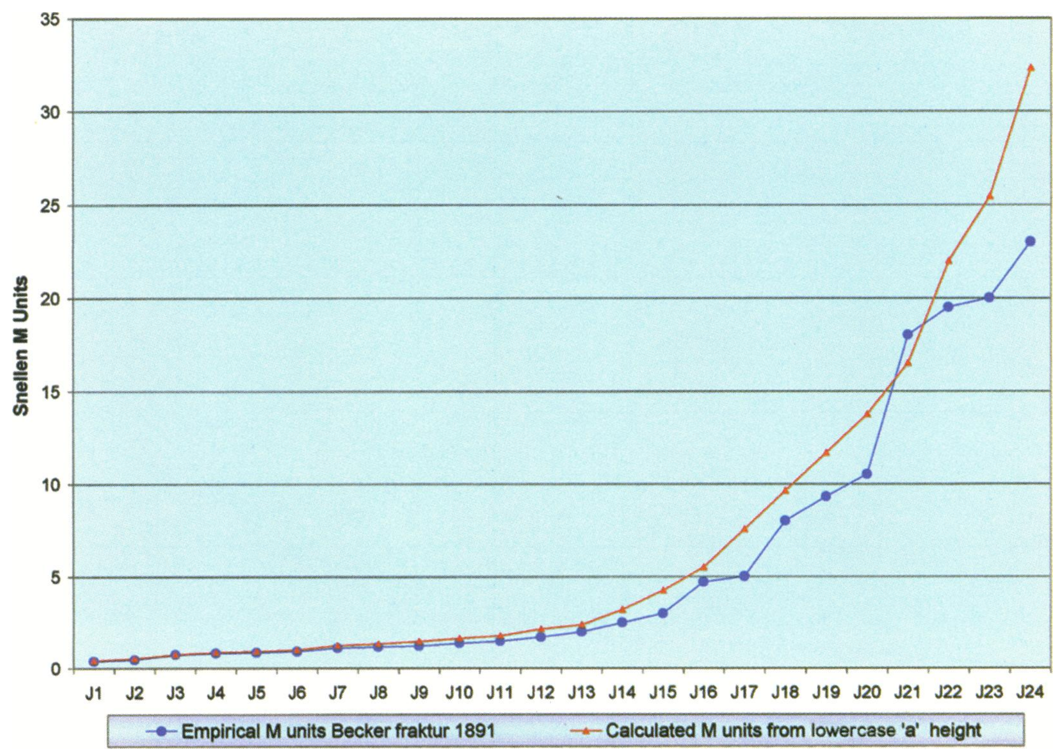


FIGURE 33

Comparison of empirical to calculated Snellen M units for Jaeger's Test-Types, standard Viennese edition, Walbaum Fraktur, as determined by Becker, 1891.

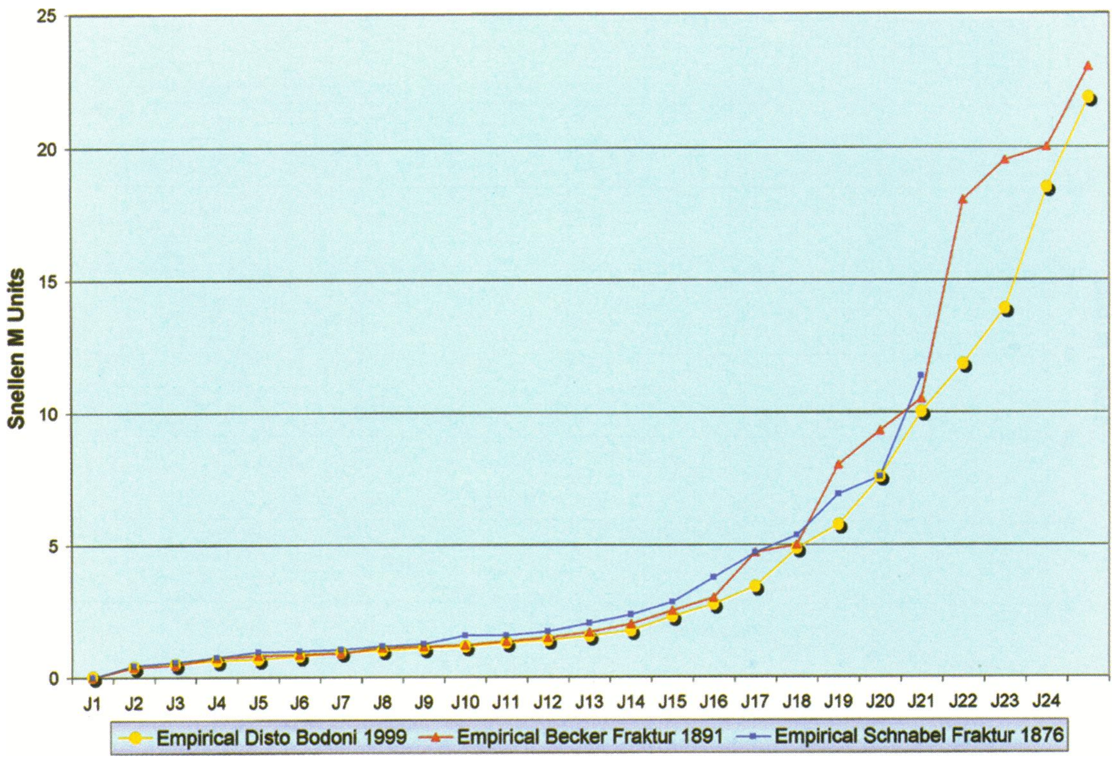


FIGURE 34

Comparison of empirical evaluation of Jaeger's Test-Types by Schnabel (1876), Becker (1891) utilizing Walbaum Fraktur with current data (1999) using English Bodoni typeface.

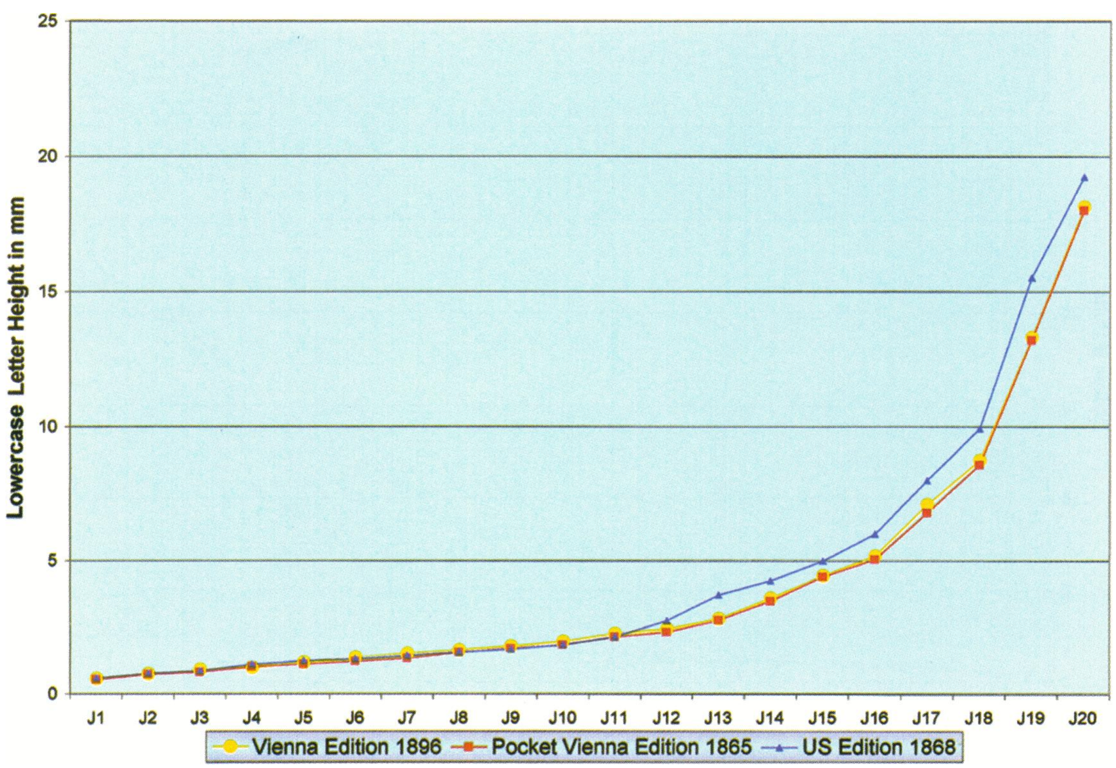


FIGURE 35

Comparison of lowercase letter height (no ascenders or descenders) English text, Bodoni font, standard Viennese edition versus Pocket Edition (1865) versus US William Wood edition (1868).

TABLE X: SNELLEN M UNITS AS CALCULATED FROM THE LOWERCASE LETTER HEIGHT OF JAEGER'S STANDARD TEST-TYPES (BODONI TYPEFACE) ARE COMPARED WITH EMPIRICALLY DETERMINED M UNITS AND CORRESPONDING ETDRS OPTOTYPES. DATA FROM THE CURRENT STUDY IS COMPARED WITH THAT OF SCHNABEL 1876 AND BECKER 1891 (BOTH FRAKTUR TYPEFACES)

	DATA FROM CURRENT STUDY (1999)							HISTORICAL DATA					
	LINEAR MEASUREMENTS			EMPIRICAL MEASUREMENTS				BECKERS DATA (1891)			SCHNABEL'S DATA (1876)		
	HEIGHT OF LOWERCASE LETTERS (MM)	M UNITS	CALCULATED M UNITS JAEGER'S TEST-TYPES	M UNITS FOR JAEGER'S TEST-TYPES	M UNITS CORRECTED FOR AXIAL LENGTH	DISTO M UNITS	CORRESPONDING ETDRS LETTERS APPEAR CLEAR	EMPIRICAL M UNITS	LETTER HEIGHT (MM)	CALCULATED M UNITS	EMPIRICAL M UNITS	LETTER HEIGHT (MM)	CALCULATED M UNITS
J1	0.54	0.4	0.4	0.4	0.39	0.37	0.4	0.38	0.6	0.41	0.45	0.61	0.42
J2	0.72	0.5	0.5	0.5	0.5	0.47	0.5	0.46	0.75	0.52	0.58	0.74	0.51
J3	0.89	0.6	0.6	0.6	0.62	0.6	0.5	0.73	1.1	0.76	0.76	1.08	0.74
J4	0.95	0.7	0.7	0.7	0.68	0.66	0.63	0.81	1.25	0.86	0.97	1.24	0.85
J5	1.15	0.8	0.8	0.8	0.79	0.77	0.8	0.85	1.35	0.93	1	1.29	0.89
J6	1.33	0.9	0.9	0.9	0.91	0.91	0.8	0.9	1.45	1	1.05	1.42	0.98
J7	1.48	1	1	1	0.99	1	1	1.1	1.8	1.24	1.18	1.74	1.2
J8	1.62	1.1	1.1	1.1	1.06	1.06	1	1.15	1.95	1.34	1.26	1.92	1.32
J9	1.77	1.2	1.2	1.2	1.16	1.13	1	1.2	2.15	1.48	1.58	2.1	1.44
J10	1.95	1.3	1.3	1.3	1.25	1.27	1.25	1.35	2.4	1.65	1.58	2.32	1.6
J11	2.25	1.5	1.5	1.4	1.36	1.37	1.5	1.48	2.6	1.79	1.73	2.62	1.8
J12	2.42	1.7	1.7	1.5	1.53	1.52	1.5	1.7	3.15	2.17	2.05	3.05	2.1
J13	2.81	1.9	1.9	1.7	1.72	1.73	1.9	2	3.5	2.41	2.36	3.5	2.41
J14	3.56	2.4	2.4	2.2	2.22	2.27	2.4	2.5	4.7	3.23	2.84	4.63	3.18
J15	4.41	3	3	3	2.72	2.73	3	3	6.2	4.26	3.77	6.09	4.19
J16	5.15	3.5	3.5	3.5	3.37	3.4	3.8	4.7	8	5.5	4.71	8.13	5.59
J17	7.06	4.9	5	5	4.91	4.84	4.8	5	11	7.57	5.36	10.99	7.56
J18	8.73	6	6	6	5.92	5.74	6	8	14	9.63	6.92	14.11	9.7
J19	13.28	9.1	9	8	7.85	7.54	7.5	9.3	17	11.69	7.57	16.93	11.64
J20	18.11	12.5	12.5	11	10.56	9.99	9.5	10.5	20	13.76	11.37	20.06	13.8
J21	21.91	15.1	15	12	12.39	11.8	12	18	24	16.51			
J22	27.09	18.6	19	15	14.51	13.9	15	19.5	32	22.01			
J23	33.65	23.1	23	18	17.63	18.46	19	20	37	25.45			
J24	43.5	29.9	30	22	22.09	21.84	24	23	47	32.32			

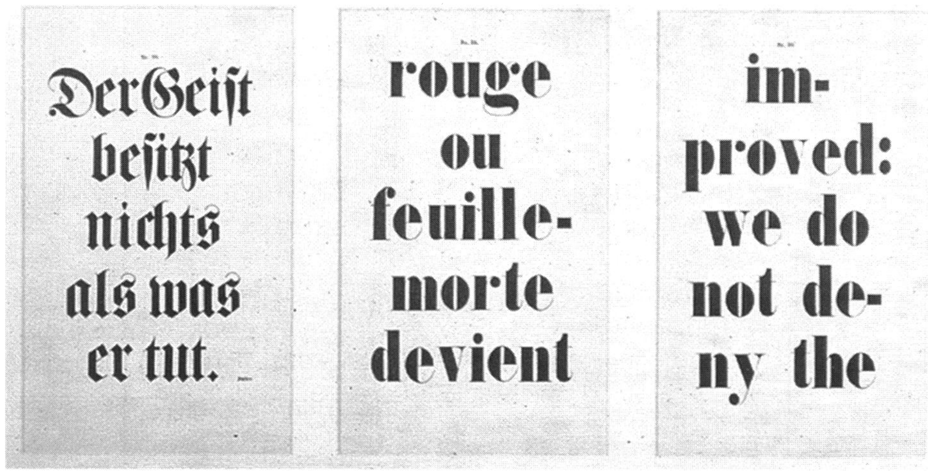


FIGURE 36A
Typefaces used by Eduard Jaeger for all of his standard edition of Test-Types printed in Vienna from 1854 through 1909. German typeface is Walbaum Fraktur and French/English is Bodoni.

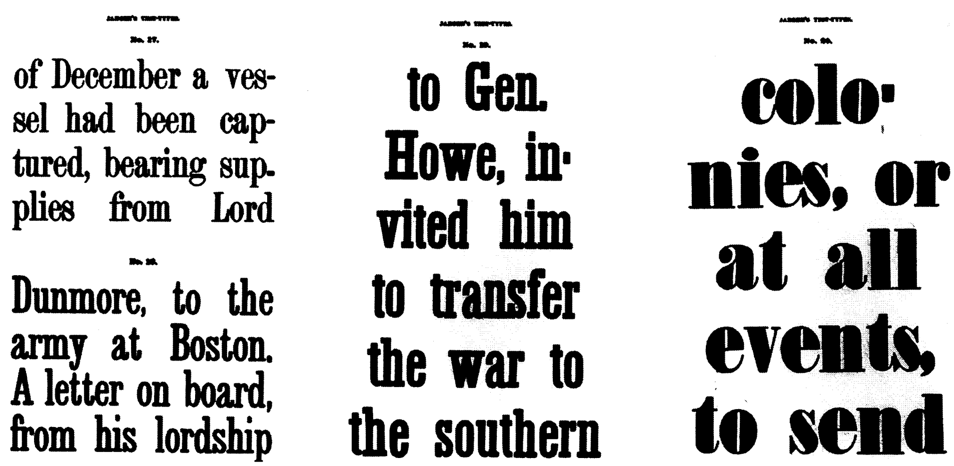


FIGURE 36B
Typefaces used to print the first US edition of Jaeger's Test- Types printed by William Wood & Co in New York in 1868. Typefaces are varied throughout, including Primer or Century for No. 17, Boton for No. 18, Tower for No. 19, and finally Bodoni for No. 20, the latter being the only typeface remotely similar to that used by Jaeger for his standard Test-Types.

only freestanding US edition of Jaeger's Test-Types published by William Wood & Co[71] in 1868 were compared. The lowercase letter heights in the standard and pocket editions published in Vienna are identical. The lowercase letter heights for the US edition are the same up to and including J11; thereafter, the letters in the US edition are consistently larger than those printed in Vienna. These data are contained in Table XI and graphically represented in Fig 35. The likely reason for the change in the letter height in the US edition is that William Wood & Co, the printer in New York, did not have access to the same fonts used by the *Staatsdruckerei* in Vienna (Fig 36A), but rather was forced to substitute from those readily available in New York City (Fig 36B). There were at least 4 editions of Jaeger's Test-Types available in the United States during the end of the 19th century. The first was the standard edition printed in Vienna or Paris. Next was the US edition printed in New York by William Wood & Co as a freestanding edition in 1868 and as an appendix to the *Treatise on Diseases of the Eye* by Carl Stellwag von Carion[72-74] in 1868, 1870, and 1873. Two other US editions were available during the same time period. The first was published as an appendix in the *Treatise on the Diseases of the Eye* by J. Soelberg Wells;[75-77] the second was contained as an appendix in *Vision: Its Optical Defects and the Adaptation of Spectacles* by Christopher Smith Fenner.[78] The latter 2 texts were published in Philadelphia, the first by Henry C. Lea in 1873, 1880, and 1883, the other by Lindsay and Blakiston in 1875. Wells, who was an ophthalmic surgeon at the Moorfields Eye Hospital in London, stated that Jaeger's Test-Types contained in his Treatise could be obtained from the "Secretary of the Royal London

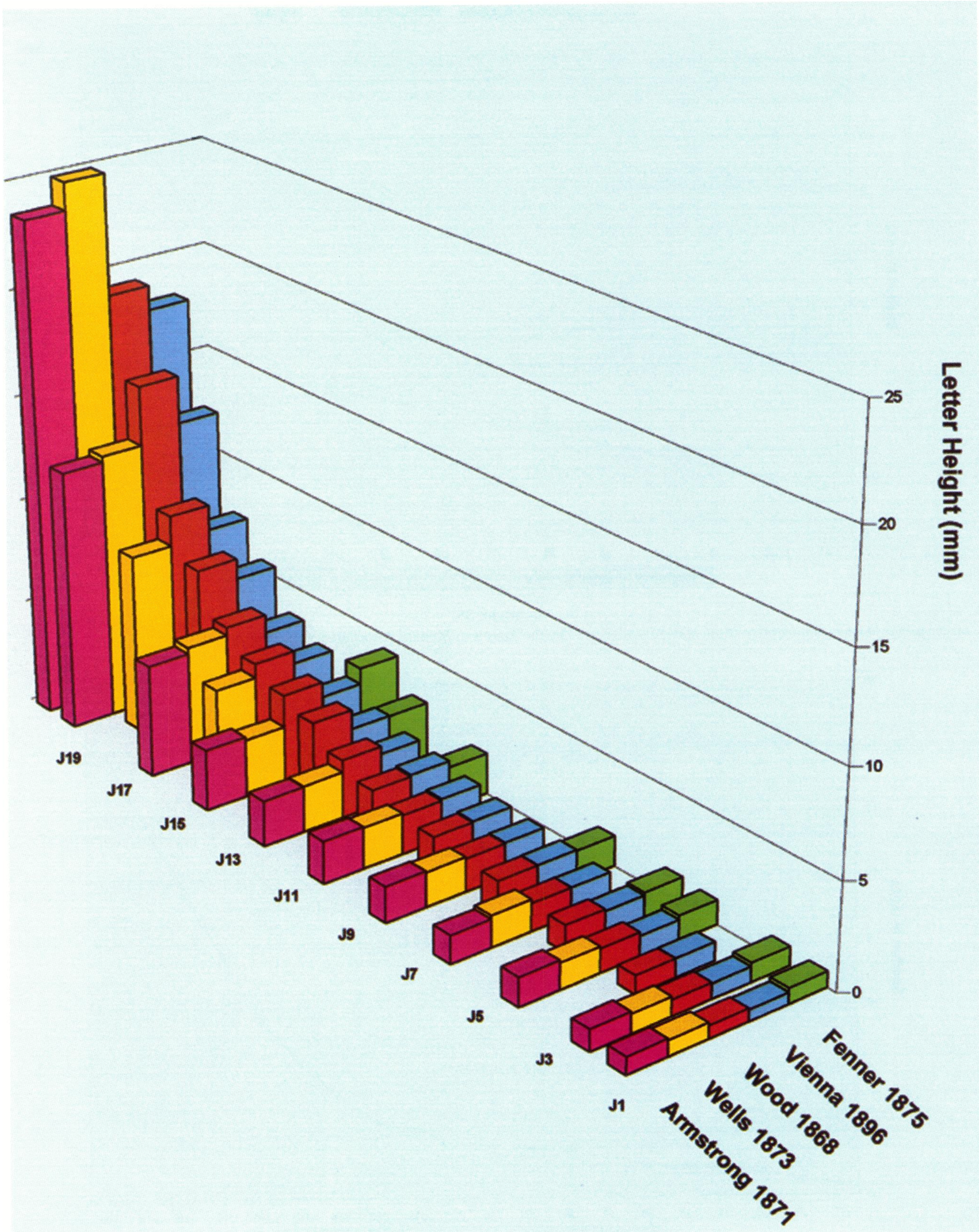


FIGURE 37

Comparison of Jaeger Test-Types letter height from Armstrong (UK, 1871), Wells (UK and US, 1873), Wood (US, 1868), Vienna (standard edition), and Fenner (US, 1875).

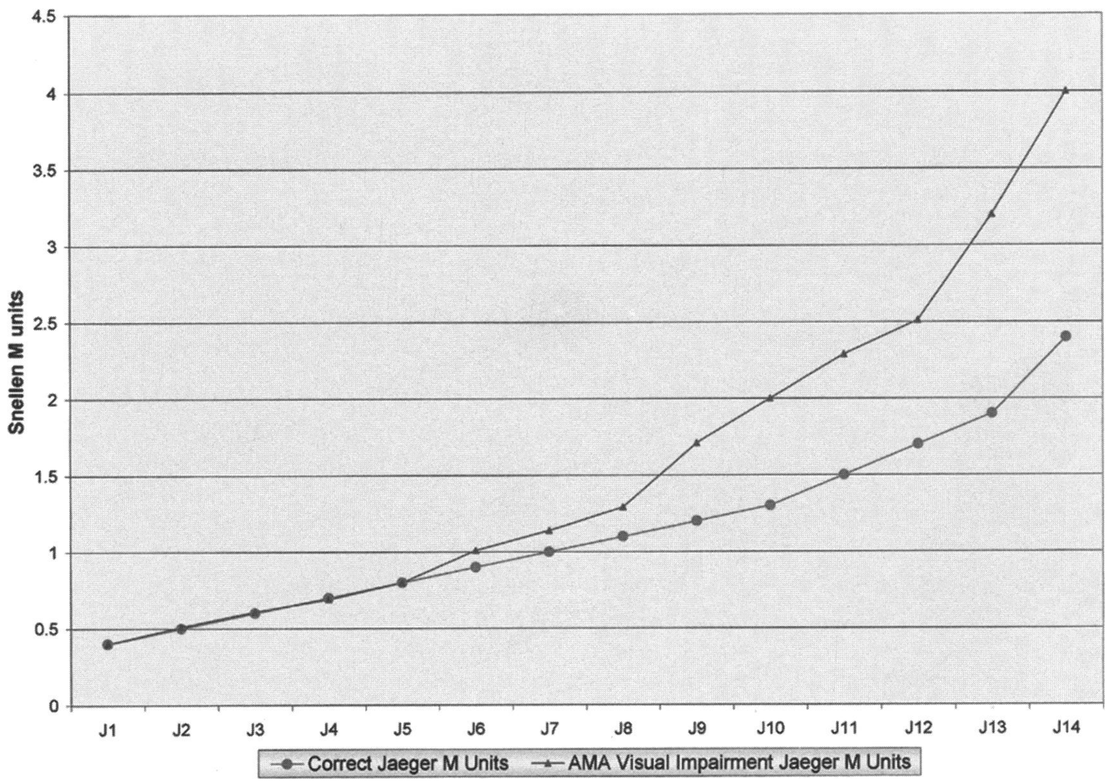


FIGURE 38
Correct Jaeger M units compared to those currently advocated by the American Medical Association Visual Impairment Guidelines.

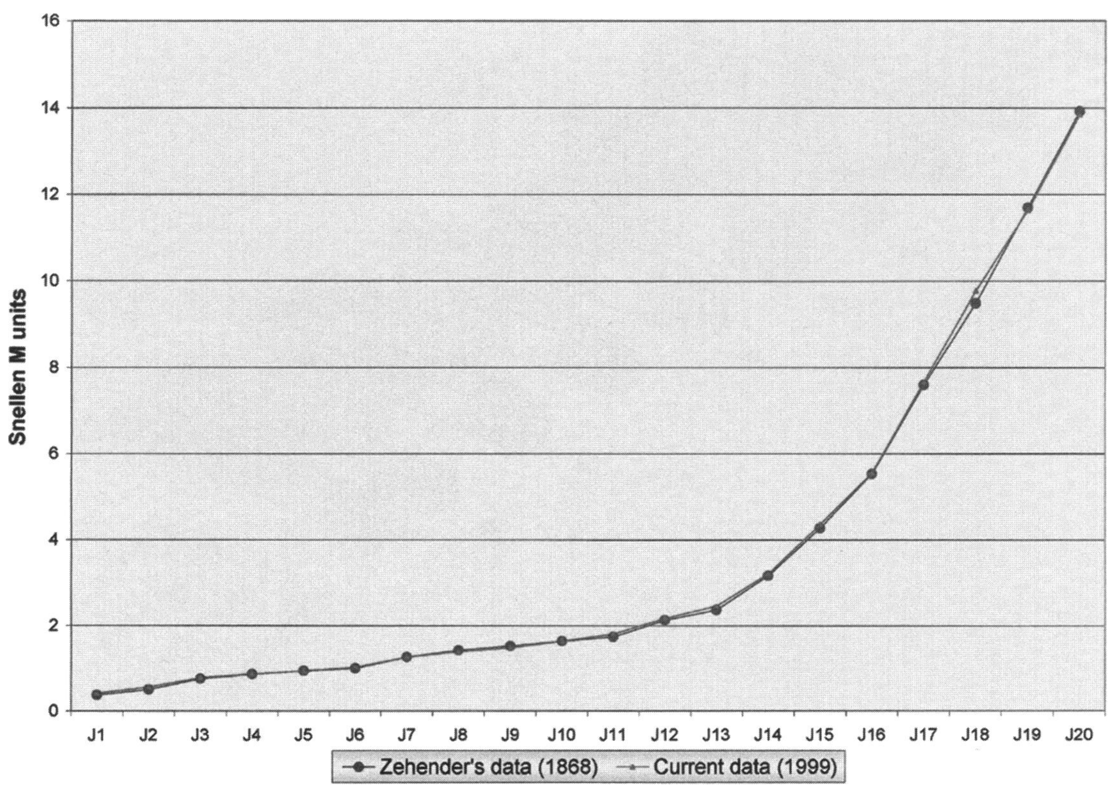


FIGURE 39
Lowercase letter height for Jaeger's Test-Types, Walbaum Fraktur obtained by Zehender (1868) compared to current measurements (1999).

TABLE XI: LINEAR MEASUREMENTS OF LOWERCASE LETTER HEIGHT OF JAEGER'S TEST-TYPES USING A MICROSCALE (MAX LEVY). STANDARD VIENNESE EDITION OF JAEGER'S TEST-TYPES WAS COMPARED TO THE 1865 POCKET EDITION PUBLISHED IN VIENNA AND THE FREESTANDING US EDITION PUBLISHED BY WILLIAM WOOD IN 1868 IN NEW YORK.

	STANDARD EDITION VIENNA	FREESTANDING WILLIAM WOOD NEW YORK 1868	POCKET EDITION VIENNA
	LOWERCASE LETTER HEIGHT IN MILLIMETERS		
J1	0.54	0.6	0.55
J2	0.72	0.77	0.73
J3	0.89	0.87	0.82
J4	0.95	1.12	1.02
J5	1.15	1.25	1.11
J6	1.33	1.32	1.22
J7	1.48	1.44	1.34
J8	1.62	1.58	1.57
J9	1.77	1.69	1.72
J10	1.95	1.86	1.85
J11	2.25	2.17	2.15
J12	2.42	2.78	2.33
J13	2.81	3.73	2.78
J14	3.56	4.26	3.48
J15	4.41	5	4.39
J16	5.15	6	5.04
J17	7.06	8	6.78
J18	8.73	9.94	8.58
J19	13.28	15.53	13.2
J20	18.11	19.24	18
J21	21.91		23.49
J22	27.09		29.13
J23	33.65		36.35
J24	43.5		43.53

Ophthalmic Hospital, Moorfields."[75] Jaeger's Test-Types contained in Well's text are virtually identical to a freestanding version published in London by Armstrong[79] from 1860 through 1920. Christopher Smith Fenner was an ophthalmologist who practiced in Louisville, Kentucky. He states in the preface of his book *Vision: Its Optical Defects and the Adaptation of Spectacles* that because of retinal hemorrhages, he was unable to complete the writing of the book, but instead had to rely on dictation and his colleagues for proofreading. The engravings in his book, which likely included Jaeger's Test-Types, were supervised by Samuel L. Fox of Philadelphia. His inability to perform his own proofreading may have been partially responsible for the differences in letter height of the Jaeger's Test-Types contained in his text.

The measured letter heights for all of the editions of Jaeger's Test-Types available in the United States during the late 1800s are contained in Table XII and graphically represented in Fig 37. Most of the letter heights are similar in all of the versions of Jaeger's Test-Types up to and including J11, after which a great deal of variability in letter height is noted. It appears as if the letter sizes in the version printed by Armstrong in the United Kingdom are close to those of the standard Vienna edition with the exception of J20, which is much larger in size. In addition, the letter heights in the Armstrong edition of Jaeger's Test-Types are almost identical to those found in the in the appendix of *Treatise on the Diseases of the Eye* by Wells. This is not unexpected, because Wells was an ophthalmic surgeon in London and the Test-Types in his *Treatise* were available at Moorfields Eye Hospital in London.

DISCUSSION

GENERAL COMMENTS

When Eduard Jaeger devoted his talents to a project, he became obsessed with perfection. This is best exemplified by observing the manner in which he dedicated himself to the creation of the drawings he produced for his atlas of the ocular fundi. He spent up to 150 hours observing and drawing each picture he created for publication. The quality of his drawings was not surpassed for at least 74 years and probably not to any degree until color fundus photography was perfected.

Jaeger subsequently directed his considerable talent,

TABLE XII: COMPARISON OF LOWERCASE LETTER HEIGHT OF SEVERAL VERSIONS OF JAEGER'S TEST-TYPES FROM THE LATE 19TH CENTURY. STANDARD VIENNA EDITION, WOOD (1868, NEW YORK), WELLS (1873, PHILADELPHIA AND UK), ARMSTRONG (1871, UK) AND FENNER (1875, PHILADELPHIA)

	STANDARD JAEGER VIENNA	WOOD, 1868 US	WELLS, 1873 US/UK	ARMSTRONG UK, 1871	FENNER US, 1875
	LOWERCASE LETTER HEIGHT IN MILLIMETERS				
J1	0.54	0.6	0.74	0.82	0.73
J2	0.72	0.77	0.92	1.02	0.9
J3	0.89	0.87			
J4	0.95	1.12	1.22	1.35	1.15
J5	1.15	1.25			1.28
J6	1.33	1.32	1.5	1.33	
J7	1.48	1.44			1.43
J8	1.62	1.58	1.65	1.7	
J9	1.77	1.69			
J10	1.95	1.86	1.95	2	
J11	2.25	2.17			1.95
J12	2.42	2.78	2.19	2.16	
J13	2.81	3.73			2.8
J14	3.56	4.26	2.74	2.9	4.32
J15	4.41	5	4.34		
J16	5.15	6	5.63	5.33	
J17	7.06	8			
J18	8.73	9.94	8.5		
J19	13.28	15.53	12.72	12.43	
J20	18.11	19.24	24.9	23.6	

TABLE XIII. SNELLEN DISTANCE EQUIVALENT ASSIGNED TO JAEGER'S TEST-TYPES BY THE AMA GUIDELINES ON VISUAL IMPAIRMENT AS PUBLISHED IN THE PDR FOR OPHTHALMOLOGY[80] 28TH EDITION, 2000, COMPARED WITH THE CORRECT VALUES

	AMA NEAR SNELLEN EQUIVALENT INCHES 14/	AMA DISTANCE SNELLEN EQUIVALENT FEET 20/	CORRECT DISTANCE SNELLEN EQUIVALENT FEET 20/
J1	14	20	20
J2	18	26	25
J3	21	30	32
J4	24	34	
J5	28	40	40
J6	35	50	
J7	40	57	50
J8	45	64	
J9	60	86	63
J10	70	100	
J11	80	114	80
J12	88	126	
J13	112	160	100
J14	140	200	125

intellect, perseverance, dedication, and obsession with detail to the production of a practical tool with which to assess visual acuity. This resulted in the development of his Test-Types. All of his contemporaries and many who followed, including Snellen, had to concede that Jaeger's Test-Types were a very practical tool for assessing visual acuity. All of the data accumulated by all of the investigators who have evaluated Jaeger's Test-Types since their

TABLE XIV: JAEGER'S TEST-TYPES EQUIVALENT SNELLEN M UNITS AS RECOMMENDED BY THE AMA GUIDELINES ON VISUAL IMPAIRMENT AND PUBLISHED IN THE PDR FOR OPHTHALMOLOGY[80], 28TH EDITION, 2000, COMPARED WITH CORRECT VALUES.

	AMA NEAR SNELLEN 35/X CM	CONVERTED TO 40/X CM	AMA VISUAL IMPAIRMENT M UNITS	CORRECT JAEGER M UNITS	PERCENTAGE ERROR JAEGER M UNITS
J1	35	40	0.4	0.4	0
J2	45	51.4	0.51	0.5	2
J3	53	60.6	0.61	0.6	1.7
J4	60	68.6	0.69	0.7	-1.4
J5	70	80	0.8	0.8	0
J6	88	100.6	1.01	0.9	12.2
J7	100	114.3	1.14	1	14
J8	113	129.1	1.29	1.1	17.3
J9	150	171.4	1.71	1.2	42.5
J10	175	200	2	1.3	53.8
J11	200	228.6	2.29	1.5	52.7
J12	220	251.4	2.51	1.7	47.6
J13	280	320	3.2	1.9	68.4
J14	350	400	4	2.4	66.7

introduction are in agreement. All 10 standard editions of Jaeger's Test-Types are a precise collection of identical typefaces, type sizes, and paragraphs of continuous text that were produced using the most sophisticated technology of the day. This resulted in a vision test that stood the test of time, being essentially unchanged from 1854 through 1909.

INACCURATE APPLICATION OF JAEGER'S STANDARD

Jaeger's nomenclature for documenting near visual acuity is still used today, primarily in the United States. For example, minimum vision standards for pilots in the United States require 20/40 or J3 for first- and second-class designations and 20/60 or J6 for third class. The US Air Force Academy requires near visual acuity correctable to 20/20 or J1 in one eye and 20/30 or J2 in the other eye in order to be commissioned as an Air Force pilot.[80(p60)]

Visual impairment evaluation guidelines published by the American Medical Association state that "For near vision, charts with print similar to that of the Snellen chart, with Revised Jaeger Standard print, or with American point-type notation for use at 35 cm (14 in) are acceptable."[80(p63)] "Snellen notation using centimeters or inches, or a comparable Revised Jaeger Standard or American point type notation, may be used in designating near visual acuity."[80(p64)] Table XIII contains the American Medical Association (AMA) recommended revised standard for Jaeger's print with Snellen M unit equivalents. When the AMA data for Jaeger letter sizes are compared with the correct Jaeger M units, little difference is noted from J1 through J5; however, the percentage error, as determined in the current study, increases consistently from J6 through J14, beginning at approximately 12% for J6 to almost 67% for J14. These data are contained in Table XIV and displayed in Fig 38. Therefore, the AMA guidelines regarding Jaeger's Test-Types are incorrect underestimating the near visual acuity by as much as 67%. For example, J14, according to AMA guidelines is equivalent to a Snellen distance visual acuity of approximately 20/200, whereas the correct Snellen distance equivalent for J14 is 20/125 (Table XIII).

HISTORICAL ANALYSIS OF JAEGER'S TEST-TYPES

Zehender's Evaluation

The first 2 analyses of Jaeger's Test-Types were performed during Jaeger's lifetime and provide a great deal of insight into the utilitarian nature of this vision test. Karl Wilhelm von Zehender, who founded *Klinische Monatsblätter für Augenheilkunde* and cofounded the Heidelberg Ophthalmological Society with Albrecht von Graefe, performed the first thorough evaluation of Jaeger's Test-Types. This took place in 1867. Zehender states in his review that on an earlier occasion he had subjected Jaeger's print scales to a rather severe critique and now that the print samples were in their fourth printing, it was time to reevaluate them. He felt that just the fact that these Test-Types were being printed for a fourth time virtually unchanged was an argument for the utility of the test.[81] Despite all of the problems that many individuals had previously mentioned condemning Jaeger's Test-Types, Zehender confessed that "almost against my will, without exception, I have in practice faithfully used Jaeger's print scales. He was uncertain whether this was from custom and fondness for Jaeger's visual test or

TABLE XV: ZEHENDER'S ANALYSIS OF THE EARLY EDITIONS OF JAEGER'S SCHRIFT-SCALEN[81] COMPARED WITH CURRENT MEASUREMENTS (1999), GERMAN FRAKTUR TYPEFACE. KARL WILHELM VON ZEHENDER, JAEGER, ED., RITTER VON JAXTTHAL. SCHRIFTSCALEN. VIERTE AUFLAGE. WEIN UND PARIS, 1867, *KLINISCHE MONATSBLÄTTER FÜR AUGENHEILKUNDE*, VI. JAHRGANG, 1868, PAGES 52-57.

	ZEHENDER'S DATA (1868)								CURRENT DATA (1999)	
						DISTANCE AT WHICH THE LETTERS IN JAEGER'S TEST-TYPES SUBTEND 5' OF ARC				
	LETTER HEIGHT					EMPIRICAL MEASUREMENTS OF SNELLEN M UNITS				
	VIENNA LINES/12	VIENNA LINES	MM	CALCULATED M UNITS	TAN 5'	VIENNA FEET	VIENNA INCHES	M UNITS	ALL LOWERCASE LETTER HEIGHT (MM) GERMAN FRAKTUR TYPEFACE	M UNITS
J1	3	0.25	0.5	0.34	1.45444207		14	0.37	0.59	0.41
J2	4	0.33	0.7	0.48			19	0.5	0.82	0.56
J3	6	0.5	1.1	0.76			28.5	0.75	1.13	0.78
J4	7	0.58	1.3	0.89			32.5	0.86	1.26	0.87
J5	7.5	0.63	1.4	0.96			35.5	0.94	1.37	0.94
J6	8	0.67	1.5	1.03			38	1	1.48	1.02
J7	10	0.83	1.8	1.24		4	48	1.26	1.83	1.26
J8	11	0.92	2	1.38		4.5	54	1.42	2.02	1.39
J9	12	1	2.2	1.51		4.8	57.6	1.52	2.15	1.48
J10	13	1.08	2.4	1.65		5.2	62.4	1.64	2.38	1.64
J11	14	1.17	2.6	1.79		5.5	66	1.74	2.63	1.81
J12	17	1.42	3.1	2.13		6.75	81	2.13	3.16	2.17
J13	19	1.58	3.5	2.41		7.5	90	2.37	3.57	2.46
J14	25	2.08	4.6	3.16		10	120	3.16	4.65	3.2
J15	34	2.83	6.2	4.26		13.5	162	4.27	6.33	4.35
J16	44	3.67	8.1	5.57		17.5	210	5.53	8.07	5.55
J17	60	5	11	7.56		24	288	7.59	11.14	7.66
J18	77	6.42	14.1	9.69		30	360	9.48	14.21	9.77
J19	93	7.75	17	11.69		37	444	11.69	16.91	11.63
J20	110	9.17	20.1	13.82		44	528	13.91	20.13	13.84
J21									24.6	16.92
J22									32.4	22.28
J23									37.9	26.07
J24									46.5	31.98

because of the advantages of using his scales to test vision."[81] From the remainder of his discussion, the latter appears to be the case.

Zehender felt that although Snellen's square letters were theoretically more precise for measuring visual angles, they were much less useful in practice because a considerable number of patients had great difficulty recognizing Snellen's unusual letters. Fraktur (German) and a modern typeface similar to Bodoni (French/English) were in common usage during the 19th century. The block letters of Snellen were virtually never used to print text. In the German-speaking world, Roman type was used rarely and was therefore much more difficult for the average German-speaking person to recognize, much less read with any degree of fluency. It is interesting to note that during January 1941 Adolph Hitler made Roman type the standard for Germany, forbidding the use of Fraktur. He stated that "gothic letters [Fraktur] were in reality 'Schwabacher-Judenletteren' [Schwabacher Jewish letters]"–a Jewish-inspired font–and from that date onward, everything in Germany would be printed using a modern (Roman) typeface.[82]

Zehender and his colleagues found that the results of their visual examinations were influenced dramatically by their patients' unfamiliarity with Snellen's unusual letterforms, and therefore eye tests composed of Snellen's letters did not produce accurate results. In contrast, virtually all of their patients were familiar with text printed using Fraktur, and therefore tests of vision using this font provided an accurate measurement of vision. Use of a

TABLE XVI: M UNITS AS CALCULATED FROM JAEGER'S STANDARD VIENNESE EDITION TEST-TYPES, LOWERCASE LETTER HEIGHT MEASUREMENTS. STANDARD SNELLEN M UNITS AND SNELLEN 20/20 EQUIVALENTS ARE ALSO GIVEN.

	HEIGHT OF ALL LOWERCASE LETTERS IN MM	CALCULATED M UNITS FOR JAEGER'S TEST-TYPES ROUNDED	EXACT SNELLEN DENOMINATOR CALCULATED	M UNITS FOR STANDARD SNELLEN PROGRESSION	APPROXIMATE SNELLEN 20/20 EQUIVALENT
J1	0.54	0.4	20	0.4	20/20
J2	0.72	0.5	25	0.5	20/25
J3	0.89	0.6	30	0.63	20/32
J4	0.95	0.7	35		
J5	1.15	0.8	40	0.8	20/40
J6	1.33	0.9	45		
J7	1.48	1	50	1	20/50
J8	1.62	1.1	55		
J9	1.77	1.2	60	1.25	20/63
J10	1.95	1.3	65		
J11	2.25	1.5	75	1.6	20/80
J12	2.42	1.7	85		
J13	2.81	1.9	95	2	20/100
J14	3.56	2.4	120	2.5	20/125
J15	4.41	3	150	3.2	20/160
J16	5.15	3.5	175	4	20/200
J17	7.06	4.9	245	5	20/250
J18	8.73	6	300	6.3	20/320
J19	13.28	9.1	455	8	20/400
J20	18.11	12.5	625	10	20/500
J21	21.91	15.1	755		
J22	27.09	18.6	930		
J23	33.65	23.1	1155		
J24	43.5	29.9	1495		

typeface that is familiar to the individual being tested not only provides the most accurate result but also is the most practical from the patients' perspective. Zehender also felt strongly that having patients read "normal" print (continuous text) was the criterion by which, in accordance with generally agreed practice, visual acuity should be measured with accuracy.[81]

Zehender realized that it was difficult to accurately determine the visual angle for continuous text because of the inherent heterogeneity in this form of printing, with its mixture of uppercase and lowercase letters being further complicated by ascenders, descenders, round, and nonround forms. However, he felt that reading continuous text was still the most practical, convenient, and accurate method of assessing vision. He also felt that using Snellen's letters to create a similar reading test would unnecessarily complicate what was otherwise a simple and practical test for everyday use.

Zehender was, however, critical of Jaeger's selection of type in that he felt that it nearly met Snellen's criteria for letter height, spacing, and size progression but that being close to what it should be was not good enough. He stated that he thought it was important to have the letter size, distance between letters, and the distance between lines increase according to a standard principle. In addition, Zehender felt that the ratio of the space between the letters to their height should remain constant.

The first edition of Jaeger's Test-Types, and most of the subsequent editions, contained a linear scale of black lines of increasing stroke width. This scale was created by Jaeger from the calculations of Stampfer, who used a similar scale to analyze various optical instruments. Zehender felt that if Jaeger had used Stampfer's data to select type samples from the extraordinary rich resources of the Imperial Royal State Printing Office in Vienna, his work would have been beyond reproach.

Zehender published a table of measurements of Jaeger's Test-Types, stating that the data had been collected from 1 of the 3 earlier editions. Table XV contains Zehender's measurements of lowercase letters, m, n, u, and i for the Fraktur typeface. The measurements are as follows: letter height, distances between letters, and distance between lines. He then calculates the approximate distance at which each size letter subtends 5 minutes of arc. All measurements are made in Viennese lines (12 per inch) or fractions thereof or Viennese inches (2.634

TABLE XVII: M UNITS AS CALCULATED FROM JAEGER'S STANDARD VIENNESE EDITION TEST-TYPE, LOWERCASE LETTER HEIGHT, COMPARED WITH EMPIRICALLY DETERMINED M UNITS. STANDARD SNELLEN M UNITS AND 20/20 EQUIVALENTS ARE ALSO GIVEN.

	HEIGHT OF ALL LOWERCASE LETTERS IN MM	CALCULATED M UNITS FOR JAEGER'S TEST-TYPES ROUNDED	ACTUAL SNELLEN DENOMINATOR CALCULATED	M UNITS FOR STANDARD SNELLEN PROGRESSION	APPROXIMATE SNELLEN 20/20 EQUIVALENT	EMPIRICAL M UNITS FOR JAEGER'S TEST-TYPE ROUNDED	ACTUAL SNELLEN DENOMINATOR EMPIRICAL
J1	0.54	0.4	20	0.4	20/20	0.4	20
J2	0.72	0.5	25	0.5	20/25	0.5	25
J3	0.89	0.6	30	0.63	20/32	0.6	30
J4	0.95	0.7	35			0.7	35
J5	1.15	0.8	40	0.8	20/40	0.8	40
J6	1.33	0.9	45			0.9	45
J7	1.48	1	50	1	20/50	1	50
J8	1.62	1.1	55			1.1	55
J9	1.77	1.2	60	1.25	20/63	1.2	60
J10	1.95	1.3	65			1.3	65
J11	2.25	1.5	75	1.6	20/80	1.4	70
J12	2.42	1.7	85			1.5	75
J13	2.81	1.9	95	2	20/100	1.7	85
J14	3.56	2.4	120	2.5	20/125	2.2	110
J15	4.41	3	150	3.2	20/160	3	150
J16	5.15	3.5	175	4	20/200	3.5	175
J17	7.06	4.9	245	5	20/250	5	250
J18	8.73	6	300	6.3	20/320	6	300
J19	13.28	9.1	455	8	20/400	8	400
J20	18.11	12.5	625	10	20/500	11	550
J21	21.91	15.1	755			12	600
J22	27.09	18.6	930			15	750
J23	33.65	23.1	1155			18	900
J24	43.5	29.9	1495			22	1100

cm per Viennese inch).

Zehender notes that the progression of Jaeger's type is neither logarithmic nor arithmetic. The current study establishes Jaeger's progression of letter size to be nearly exponential (Fig 21). Zehender stated that Jaeger's type samples have almost a constant ratio of letter height to letter thickness, being nearly 5:1 in all samples with the exception of 4:1 in some of the smaller fonts. The major irregularity he found with Jaeger's type was the variability in intraline distance.

Zehender also notes that from type size N14 through N20, the text is gradually reduced from paragraphs to single words, with the letter spacing decreasing as well. In later editions, which contain the N21 through N24 type sizes, the text is further reduced to just a few letters. Zehender realized that "the distance between the letters should increase or decrease in a ratio as close as possible to the size of the letters."[81]

Zehender explains the discrepancy in the visual angle as calculated from letter height measurements when compared to the empirical measurements being related to the variation in letter and line spacing "the crowding phenomenon."[81] Figure 39 compares the lowercase letter heights as measured by Zehender in 1868 to those measured from Jaeger's standard Test-Types in the current study. Both sets of data were obtained from the German text printed using Fraktur and are virtually identical.

Schnabel's Evaluation

The second individual to analyze Jaeger's Test-Types was Dr J. Schnabel, Jaeger's student and assistant. He published his extensive analysis in 1876. Several years prior to this publication, Schnabel stated that he had had the opportunity of working with Professor von Jaeger in evaluating Jaeger's Test-Types.

Schnabel collected objective measurements of Jaeger's text and also obtained empirical data by measuring the distance as which patients with normal vision (Snellen 20/20) could see the type samples clearly. He concluded from his data that for type samples N1 through N13, both measurements were equivalent. However, type samples from N14 to N20 required a much larger visual angle than 5 minutes to be seen clearly. This was due to the fact that in the larger type samples, the spaces between the vertical strokes of the letters are narrower than the strokes themselves and that the letters and lines are placed too close together, thereby causing the samples to exhibit the crowding phenomenon. Figure 26 depicts the decrease in letter and line spacing as the fonts increase in size. He remedied this situation by cutting individual letters apart and remounting them so that the smallest distance between the letters equaled half the height of the letter, while the distance between words and lines was equal to the letter height. After making these alterations, all of the type samples could then be read by a normal eye at an angle of vision of at least 5 minutes of arc. All of Schnabel's measurements were made from the German Fraktur type samples. Measurements were collected using Paris lines (12 per inch), Paris inches (1 Paris inch = 2.708 cm), and Paris feet (12 inches per foot). Schnabel's data are contained in Table VII and presented in Fig 28. The data collected by Zehender and Schnabel along with current comparable data, all of which were obtained from Jaeger's standard edition Test-Types, are contained in Table XIV and displayed in Fig 35.

CURRENT EVALUATION OF JAEGER'S TEST-TYPES

Linear Measurements

Extensive comparative analysis of all of the standard editions of Jaeger's Test-Types has been undertaken, which has heretofore never been accomplished. In addition, all of the early US editions and 2 early UK editions have been analyzed. All of the previous analyses of Jaeger's Test-Types have been translated, and the data have been reviewed. The instruments used to collect the data for the current study are more accurate than those available to previous investigators. All of Jaeger's 10 standard editions of his Test-Types were directly compared, one to another, by using transparent overlays. The text, typefaces, and letter sizes in all editions were in this manner determined to be identical with few exceptions

The initial evaluation of Jaeger's standard Test-Types included examining 2 subpopulations of lowercase letters: line letters (i, m, n, r, u, v, w, x, z) and round letters (c, e, o). This was done for 2 reasons. The first was historical in that when previous investigators evaluated Jaeger's Test-Types, they were inconsistent in terms of which subgroup of lowercase letters they decided to evaluate. Some chose to measure line letters, whereas others measured round letters. It was therefore necessary to measure the heights of subpopulations of letters in order to compare the current data with historical measurements. For example, Snellen (1873), Pergens (1906), and Birkhäuser (1918) measured Bodoni line letters. Williams (1904) and Public Health Report (1931) measured Bodoni round letters. Zehender (1867), Schnabel (1876), and Becker (1891) measured Fraktur letters. The second reason for breaking the letters into subpopulations prior to collecting letter height measurements was the suggestion that there would be a considerable difference between the heights of these 2 groups of letters. These differences turned out to be insignificant (Table III and Fig 20), and therefore in the final analysis, the average height of all of the lowercase letters (without ascenders and descenders) was utilized. When a line of continuous text is visualized, the eye perceives an average of the height of the bodies of the lowercase letters. Letter descenders provide little information to the reader, since text legibility is not affected by covering the descenders.[83] However, the eye must perceive the bodies of the lowercase letters, with a relative degree of clarity, in order to read text efficiently.

The validity of the measurements for the lowercase letter heights in the current study is confirmed by the close correlation with data collected by all 8 previous investigators from 1867 through 1931. All sets of data are virtually identical. The consistency in the empirical measurements obtained in the current study when compared to the similar studies of Schnabel, Snellen, and Becker add further validity to the current data.

Empirical Measurements

Comparison of the empirical data with the calculated M units from the measurement of letter height demonstrates that a larger visual angle than would be predicted from the letter height is required to see the letters clearly for the larger font sizes, the disparity beginning subtly at about J18 and gradually increasing with increasing size.

Zehender, Schnabel, and Becker recognized this problem, stating that the larger fonts used by Jaeger did not maintain the correct interletter and interline spacing to prevent the crowding phenomenon. Schabel corrected this problem by cutting the larger letters apart, remounting them with the proper spacing, and redoing the empirical measurements. He states that by correcting the letter spacing, the visual angle determined by both methods is identical. Therefore, the visual angle of continuous text can be accurately determined by measuring the height of the body of the lowercase letters. Using this method, Jaeger's Test-Types were assigned their correct Snellen M units.

One additional experiment was performed to compare empirical measurements of Snellen optotypes with those of Jaeger continuous text. Using the previously described experimental protocol with the addition of placing a standard ETDRS eye chart above the page of Jaeger text, identical data were collected. After determining the distance at which the Jaeger text became clear, the subject was asked to look at the ETDRS eye chart and state which line was clear. Figures 28A, B, and C demonstrate this task. The data, presented in Table XI, demonstrate excellent correlation of both empirical measurements (ie, the ETDRS data and Jaeger empirical data are virtually identical).

The Loss of the Standard for Jaeger's Test-Types
The final question to be answered is how, when, why, and where was the standard that Jaeger worked so hard to establish and maintain lost? To answer this question, all of the available early US and several of the UK versions of Jaeger's Test-Types were located and evaluated. These included the only freestanding US edition, which was published by William Wood & Co in New York in 1868. Three additional versions of Jaeger's Test-Types were evaluated:

- *A Treatise on the Disease of the Eye* by J. Soelberg Wells, 1873, as an appendix
- *Vision: Its Optical Defects* by C.S. Fenner, 1875, as an appendix
- Jaeger's freestanding Test-Types published by Armstrong in London in 1871

Lowercase letter heights were measured for all of these additional 19th century versions of Jaeger's Test-Types. The standard Vienna edition, the 1868 US edition, the 1871 Armstrong UK edition, the 1873 Wells US and UK edition, and the Fenner 1875 US edition were compared to each other. The smaller type sizes are very similar in size for all of these versions of Jaeger's Test-Types until J12; thereafter, the larger type sizes demonstrate significant disparity. It is interesting to note, however, that the two British versions of the Test-Types, one by Wells and the other by Armstrong, are very similar to each other and to the original version of Jaeger's Test-Types printed in Vienna. The disparity in the type sizes for Jaeger's Test-Types was therefore introduced when the vision test was printed for the first time outside of Vienna or Paris. This was minimal in the editions printed in the United Kingdom; however, in the editions printed in the United States, the disparity was significant. Apparently, the print houses in the United Kingdom and the United States did not have access to the same typefaces that were available in Vienna and Paris.

Standardization of Type Libraries
Although Pierre Simon Fournier made the first attempt to develop a uniform system and nomenclature for type in Paris in 1737, no such system was established in the United States. Fournier is credited with establishing the printer's point system. By chance, 100 of Fournier's points equal 35 mm. The metric system was not in place during Fournier's lifetime and was only adopted in 1875 by the signing of the Treaty of the Metre in Paris. At a time when Fournier's point measurement system was well ingrained in Paris and presumably Vienna, pica measurement was still being used in the United Kingdom and the United States. The American point system was finally established at a meeting of the US Type Founders' Association held in Niagara Falls, NY, in 1886. In the American point system, 996 points equal 35 cm. It is therefore likely that the US system was unwittingly derived from Fournier.[54]

CONCLUSIONS

Jaeger's Test-Types have been thoroughly analyzed and the following conclusions achieved.

1. All of the Test-Types printed in either Vienna or Paris from 1854 through 1909 including the pocket edition of 1865 contain identical typefaces and letter heights for the corresponding Jaeger numbers.
2. Comparing the linear measurements for all of the data previously collected by 8 investigators, from 1867 (Zehender) through 1931 (Public Health Reports), the measured letter heights are virtually identical to each other and to current measurements.
3. The correct numbers for the letter height and M units for Jaeger's Test-Types (modern English/French, Bodoni) are contained in Table XVI.
4. Linear and empirical measurements of the visual angle of Jaeger's Test-Types are identical up to and including J18 when the larger letters become more difficult to distinguish because they do not maintain the appropriate interletter and interline distances. That is, the larger type sizes in Jaeger's Test-Types exhibit the crowding phenomenon. This data are depicted in Table XVII. Linear and empirical measurements demonstrate good correspondence when letter and line spacing are appropriate.
5. The visual angle of a line of continuous text is best approximated by measuring the height of the bodies of the lowercase letters without ascenders or descenders.
6. The Jaeger standard for his Test-Type was lost when the first US version was printed in 1868 by William Wood & Co in New York City. This occurred because rather than importing the correct typeface from Vienna, William Wood & Co substituted their own fonts. To further complicate this issue, several additional nonstandard versions of Jaeger's Test-Types were printed in the United States and the United Kingdom during the end of the 19th century using typefaces different from the Jaeger Viennese standard and different than that used in the original US version printed by William Wood & Co. This resulted in the complete loss of any standard for

Jaeger's Test-Types in the United States, this problem continues to the present day.

Until late in the 19th century, when the American Type Library was established, there was no standard for any typeface in the United States. This would have made it nearly impossible for 2 different printers in the United States to produce identical vision tests. An appreciation of the state of the art of printing in the latter part of the 19th century clearly explains why and how the precise standard established and maintained for over half a century by Eduard Jaeger was lost. We are finally in a position to correct this shortcoming.

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[1] Paris, England, Sweden, Poland, Prussia, Bavaria, Hanover, Saxony, Wirtembergh, Baden, Brunswich, Dessen Oldenberg, Bremen, Frankfurt, Hamburg, Lubeck, Amsterdam, Kostock, Rome, Naples, Portugal, and Spain. It is stated that the Prussian foot is also used in Sleswig, Denmark, Norway, Mecklenburg, Strelitz, Jever in the Anhalt-Territories, in Shwarzburgh, Sondershouse and the sub-dominion of Shwarzburgh-Rudolstadt. The Baden foot is also used in Nassau and Switzerland. The Hamburg foot is used in Holstein, Mecklenburgh and Swerin. The Stuttgard foot in Hobenzollern. The Frankfurt foot in Hamburg. The meter in the Netherlands, Belgium, Sardinia, Milan, Modena, Venice, Corsica and Greece. The English foot in Russia, the United States of America, Canada, Jamaica, and Polynesia. The Spanish foot in Havana, Mexico, Peru, Uruguay, Chile, Venezuela, New Granada and the Philippines. The Portuguese Pé is also adopted in Brazil. Baden, Switzerland, Nassau, Wirtemberg, Hohenzollern and Sweden subdivide their foot in 10 inches with 10 lines each.; Rome gives four palms each pede: Naples has instead of feet palmos, consisting of 10 decimas, with 10 centesimos.